Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 195 MARCH, 1923 No. 3

ANALYSIS OF AIRPLANE FACTORS.*

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PREFACE.

It is sometimes useful to forecast the performance of an airplane from the known coefficients of its wing profile; also to compare by such means the performance of an airplane equipped successively with different wings. The airplane factors occasionally used in such forecast and comparison are here derived and graphically illustrated. The text is a slightly revised form of a report prepared for the Bureau of Aeronautics by the present writer, and dated June 1, 1922. The diagrams were made by Mr. R. M. Bear.

I. WING FORCES AND COEFFICIENTS.

Lift and Drag.—The lift and drag of a wing model are the components of the air force respectively across and along the undisturbed direction of the air stream. The lift L and drag D of an aerofoil of area S, in straight and steady translation at speed V, through air of density ρ, may be written

$$L = C_L \frac{\rho}{2} SV^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$D = C_D \frac{\rho}{2} SV^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

* Communicated by the Author.

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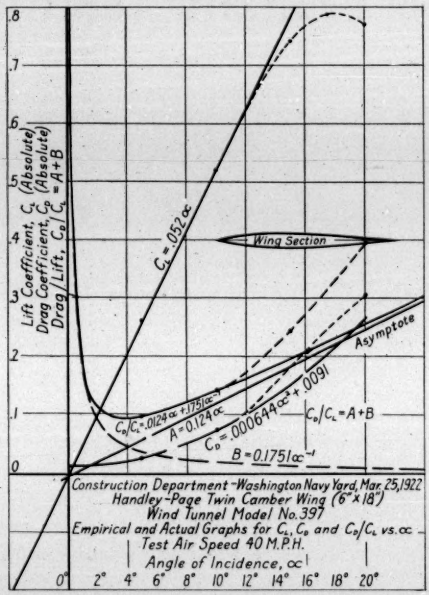
where C_L and C_D are shape coefficients which, for simplicity, are assumed to be fairly constant while the shape and presentation of the model to the wind remain fixed. In (1), (2), and throughout this text, one ignores the value of Reynold's number Vl/υ,

FIG. 1.


Lift Coefficient, C_L (Absolute)
Drag Coefficient, C_D (Absolute)
Drag/Lift, $C_D/C_L = A+B$
$C_L = .052\alpha$
Wing Section
Asymptote
$C_D/C_L = .0124\alpha + .1751\alpha$
$A = 0.124\alpha$
$C_D = .00064A\alpha^2 + .0091$
$C_D/C_L = A+B$
$B = 0.1751\alpha^{-1}$
Construction Department-Washington Navy Yard, Mar. 25, 1922
Handley-Page Twin Camber Wing (6" x 18")
Wind Tunnel Model No. 397
Empirical and Actual Graphs for C_L, C_D and C_D/C_L vs. α
Test Air Speed 40 M.P.H.
Angle of Incidence, α
0° 2° 4° 6° 8° 10° 12° 14° 16° 18° 20°
.8 .7 .6 .5 .4 .3 .2 .1 0

where υ is the kinematic viscosity of the air, and l is some length such as the span or chord of the wing.

Lift and Drag Coefficients.—For a great variety of aerofoils the lift is a linear, the drag a quadratic function of the angle of attack α, when this ranges through the usual flying incidences. Hence if α is referred to the wing chord

$$C_L = a'\alpha + b' \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (3)$$

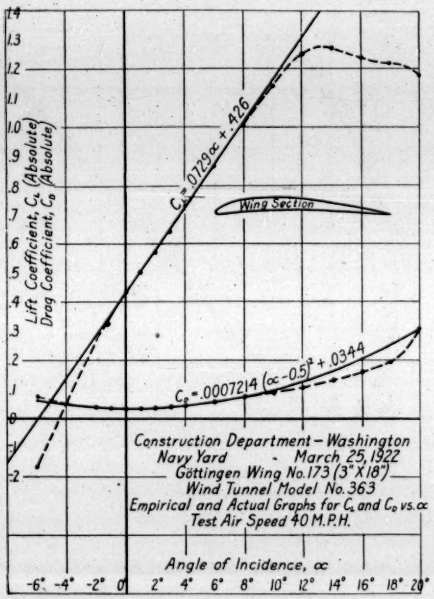
$$C_D = c'\alpha^2 + d'\alpha + e' \quad \cdots\cdots\cdots\cdots \quad (4)$$

$$= a\,C_L^2 + b\,C_L + c \quad \cdots\cdots\cdots\cdots \quad (5)$$

in which all the small-letter coefficients are constants easily obtainable from the experimental lift and drag diagrams. From (3), (4), (5), it is easily found that

$$a = c'/a'^2$$
$$b = (a'd' - 2b'c')/a'^3 \qquad \cdots\cdots\cdots (6)$$
$$c = (b'\,c' - a'b'd' + a'^3 e')/a'^3$$

FIG. 2.

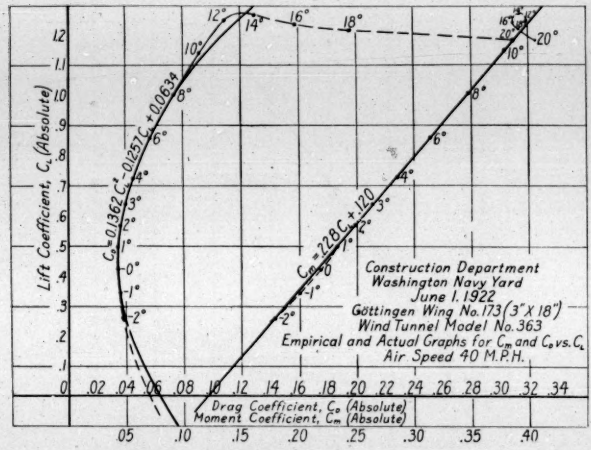

Lift Coefficient, C_L (Absolute)
Drag Coefficient, C_D (Absolute)
$C_L = .0729\alpha + .426$
Wing Section
$C_D = .0007214\,(\alpha - 0.5)^2 + .0344$
Construction Department – Washington
Navy Yard - March 25, 1922
Göttingen Wing No. 173 (3" X 18")
Wind Tunnel Model No. 363
Empirical and Actual Graphs for C_L and C_D vs. α
Test Air Speed 40 M.P.H.
Angle of Incidence, α
-6° -4° -2° 0° 2° 4° 6° 8° 10° 12° 14° 16° 18° 20°

For a twin-camber wing, for which $b' = 0$, (3) is the straight line $C_L = a'\alpha$ through the origin; (4) is the parabola $C_D = c'\alpha^2 + e'$, with its vertex at (o, e'); (5) becomes $C_D = a\,C_L^2 + c$, where $c = e'$. Thus all the second terms of the second members of (3), (4), (5), are zero. For many shapes also of wings not twin-cambered d' and $b\,C_L$ are zero while b' is not. If α is referred to the null line, $b' = 0$ always. C_L/C_D *versus* α **is a**

cubic; C_D / C_L *versus* α a hyperbola (Fig. 1). Also D/L *versus* α is a hyperbola; hence D *versus* α is, too, when L is a constant load.

The accuracy of (3) and (4) in two favorable cases is illustrated in Figs. 1 and 2; and the accuracy of (5) is disclosed in Fig. 3. The equations to these curves are purely empirical, that is, they are made to accord with faired wind-tunnel data irrespective of

FIG. 3.


Lift Coefficient, C_L (Absolute)
$C_L = 0.1362\,C_o^2 - 0.1257\,C_o + 0.0634$
$C_L = 2.28\,C_o + 1.20$
$C_o = 0$
Construction Department
Washington Navy Yard
June 1. 1922
Göttingen Wing No. 173 (3" X 18")
Wind Tunnel Model No. 363
Empirical and Actual Graphs for C_m and C_o vs. C_L
Air Speed 40 M.P.H.
Drag Coefficient, C_o (Absolute)
Moment Coefficient, C_m (Absolute)

any physical theory. In general, the wind-tunnel lift and drag for a considerable range of incidence can not be simply and perfectly expressed by either rational or empirical formulæ. The present illustrations show that the actual lift and drag coefficients sometimes can be algebraically expressed with sufficient precision to be practically useful.

Pitching Moment Coefficient.—In general L and D exert a pitching moment M about any transverse line, say the leading edge of the wing. The coefficient of pitching moment is usually written

$$C_m = M / \frac{\rho}{2} c S V^2 \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

where c is the mean chord length of the wing. For many aerofoils

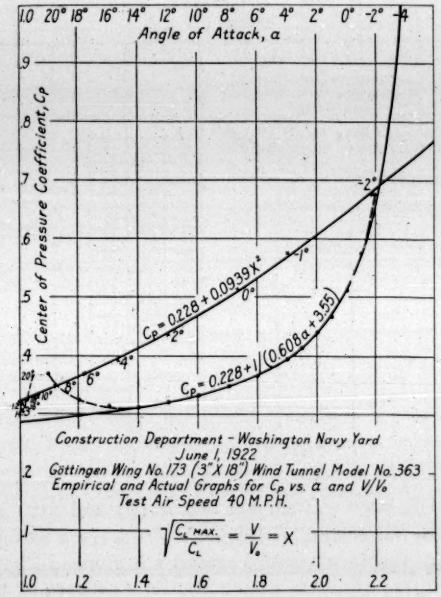
C_m, for α small, is a linear function of C_L, as shown in Fig. 3, in which it has the form

$$C_m = fC_L + g \quad \cdots\cdots\cdots\cdots\cdots \quad (8)$$

Hence when f and g are constants, C_m plots against C_D as a parabola, as illustrated in Fig. 3.

Centre of Pressure Coefficient.—If l is the distance of the centre of pressure from the leading edge, one may write approxi-

FIG. 4.


Angle of Attack, α
Center of Pressure Coefficient, Cp
Cp = 0.228 + 0.0939 X²
Cp = 0.228 + 1/(0.608α + 3.55)
Construction Department - Washington Navy Yard
June 1, 1922
Göttingen Wing No. 173 (3" X 18") Wind Tunnel Model No. 363
Empirical and Actual Graphs for Cp vs. α and V/Vo
Test Air Speed 40 M.P.H.
√(CL MAX. / CL) = V/Vo = X

mately $M = Ll$, for small angles of attack and large efficiency L/D. Then (7) becomes

$$l/c = C_m/C_L = C_p \quad \cdots\cdots\cdots\cdots \quad (9)$$

where C_p is the centre of pressure coefficient. And since $C_m = fC_L + g$, (9) becomes, for these small angles,

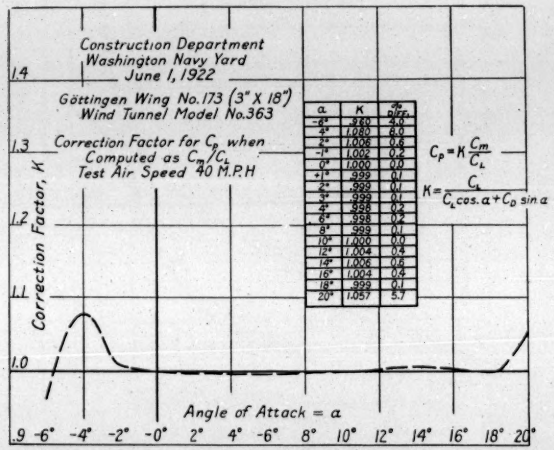
$$C_p = f + g/C_L \quad \cdots\cdots\cdots\cdots \quad (10)$$

or the distance l of the centre of pressure, for such conditions, is a quadratic function of the speed $\sqrt{C_L}$ max$/C_L$ as given by (11) below. Fig. 4 shows the agreement of (10) with the experimental data for a typical wing. The more familiar graph of C_p *versus* α, shown in Fig. 4, is the hyperbola got from (3) and (10),

$$C_p = f + g/(a'\alpha + b') \quad \cdots\cdots\cdots\cdots \quad (10_1)$$

When the range of α is large, one should write, for exact-

FIG. 5.


Construction Department
Washington Navy Yard
June 1, 1922
Göttingen Wing No. 173 (3" X 18")
Wind Tunnel Model No. 363
Correction Factor for C_p when
Computed as C_m/C_L
Test Air Speed 40 M.P.H
Correction Factor, K
Angle of Attack = α
$C_p = K\frac{C_m}{C_L}$
$K = \frac{C_L}{C_L \cos.\alpha + C_D \sin\alpha}$
α | K | Diff.
-6° | 9.60 | 4.0
-4° | 1.080 | 6.0
-2° | 1.006 | 0.6
-1° | 1.002 | 0.2
0° | 1.000 | 0.0
+1° | 999 | 0.1
2° | 999 | 0.1
3° | 999 | 0.1
4° | 998 | 0.2
6° | 998 | 0.2
8° | 999 | 0.1
10° | 1.000 | 0.0
12° | 1.004 | 0.4
14° | 1.006 | 0.6
16° | 1.004 | 0.4
18° | 999 | 0.1
20° | 1.057 | 5.7
1.4
1.3
1.2
1.1
1.0
.9
-6° -4° -2° -0° 2° 4° 6° 8° 10° 12° 14° 16° 18° 20°

ness, $M = l(L \cos \alpha + D \sin \alpha)$; that is (9) and (10) must be multiplied by the correction factor $C_L/(C_L \cos \alpha + C_D \sin \alpha)$. The value of this factor plotted against α is given in Fig. 5 for a typical aerofoil. It differs from unity, for α between 0° and 10°, by a small fraction of 1 per cent.

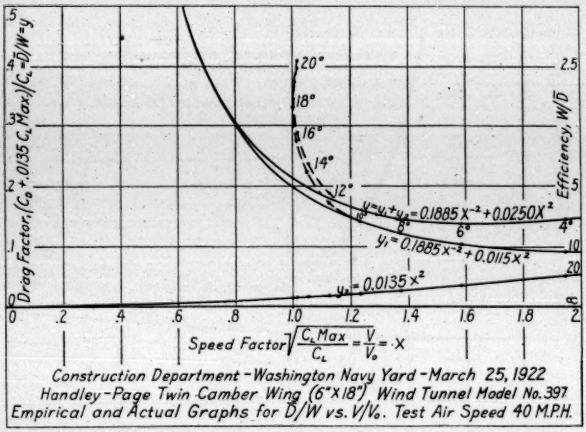
In engineering practice, for the more usual flying angles, one finds l numerically as $l = M/L$ or cC_m/C_L; and graphically by drawing a straight line through the origin on a diagram of C_m *versus* C_L to cut this curve at (C_m, C_L) and to cut the line $C_L = c$ at a point which by (10) must necessarily be (l, c), and hence gives l directly. This graphic method is applicable also to

the *M versus L* diagram where the straight line $L = 1$ is cut at the point $(l, 1)$.

II. AIRPLANE FACTORS.

The Speed Factor.—If the weight, $W = \frac{1}{2} C_L \rho S V^2 = L$, of

FIG. 6.


Drag Factor, $1/C_0 + 0.135\, C_L Max)/C_L = D/W = y$
Efficiency, W/D
20°
18°
16°
14°
12°
$y = y_1 + y_2 = 0.1885\,x^{-2} + 0.0250\,x^2$
$y_1 = 0.1885\,x^{-2} + 0.0115\,x^2$
$y_2 = 0.0135\,x^2$
Speed Factor $\sqrt{\frac{C_L Max}{C_L}} = \frac{V}{V_0} = x$
Construction Department - Washington Navy Yard - March 25, 1922
Handley-Page Twin Camber Wing (6"x18") Wind Tunnel Model No. 397
Empirical and Actual Graphs for D/W vs. V/V₀. Test Air Speed 40 M.P.H.

an airplane in straight horizontal translation is sensibly constant, the speed V can be written

$$V = V_0 \sqrt{\rho_0/\rho}\ \sqrt{C_L \max/C_L}, \quad \cdots\cdots\cdots\cdots \quad (11')$$

or

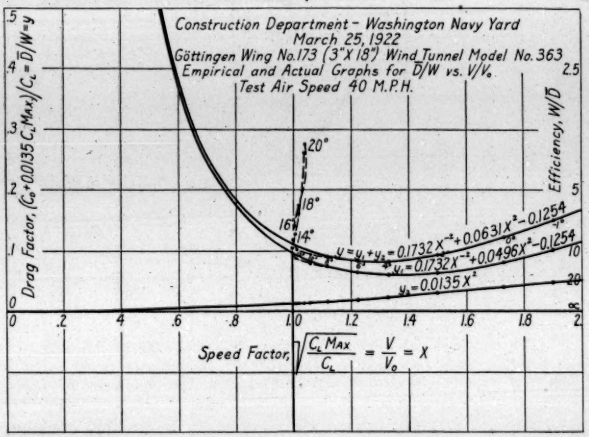
$$V = V_0 \sqrt{C_L \max/C_L}, \text{ for } \rho \text{ constant} \quad \cdots\cdots\cdots \quad (11)$$

in which C_L is the wing-lift coefficient, and the multiplier of V_0 in (11) is called the "*speed factor.*" This latter is the actual speed in terms of the slowest speed, $V_0 = \sqrt{2W/C_L \max \rho_0 S}$, as unit.

Density Factor.—If the air density varies, one obviously must use the form (11′) wherever V enters as a factor. Unless otherwise stated, ρ in the following text will be assumed constant, that is, the "*density factor*" $\sqrt{\rho_0/\rho} = 1$.

The Drag Factor.—The drag $\overline{D} = \frac{1}{2}\rho S V^2 (C_D + C'_D)$, of said airplane, comprises two terms: The first being the main planes drag, whose coefficient is C_D ; the second being an addition to C_D to represent the parasite resistance. In practice it appears that one may write $C'_D = n\, C_L$ max, where n is a numeral averaging about .0135 for different machines, and not greatly different for

FIG. 7.


Construction Department – Washington Navy Yard
March 25, 1922
Göttingen Wing No.173 (3"X 18") Wind Tunnel Model No. 363
Empirical and Actual Graphs for D/W vs. V/V₀
Test Air Speed 40 M.P.H.
Drag Factor, (C₀+0.0135 C_L Max)/C_L = D/W = y
Efficiency, W/D
Speed Factor, √(C_L Max / C_L) = V/V₀ = X
20°
18°
16°
14°
y = y₁ + y₂ = 0.1732 X⁻² + 0.0631 X² − 0.1254
y₁ = 0.1732 X⁻² + 0.0496 X² − 0.1254
y₂ = 0.0135 X²

various types. Using n and noting that $\frac{1}{2}\rho S V^2 = W/C_L$, the drag becomes

$$\overline{D} = W(C_D + n\, C_L \max)/C_L \quad \cdots\cdots\cdots \quad (12)$$

whose multiplier of W is called the "*drag factor.*" It is the actual drag in terms of W as unit. One should distinguish $\overline{D}$ of (12) from D of (2).

Power Factor.—Multiplying the drag by the speed V gives the towline power

$$P = WV_0\sqrt{C_L \max / C_L}\,(C_D + n\, C_L \max)/C_L \quad \cdots\cdots\cdots \quad (13)$$

whose multiplier of WV_0 is called the "*power factor.*" It is the actual power in terms of WV_0 as unit. If the density varies, the power factor obviously must be multiplied by the density factor $\sqrt{\rho_0/\rho}$, as shown in (11′).

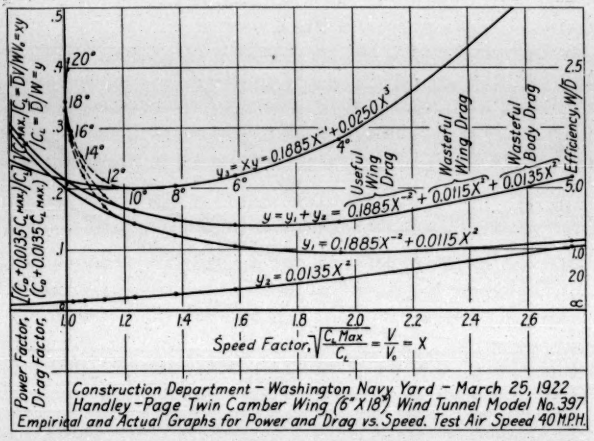
It sometimes is assumed that at high speed $C_D = n\,C_L$ max; hence $C_D^2/C_L^3 \propto P^2$. In any case

$$(C_D + n\,C_L \max)^2/C_L^3 \propto P^2 \quad \cdots\cdots\cdots (13_1)$$

III. PERFORMANCE OF CONSTANT-WING AIRPLANE.

Drag-speed Curve.—Plotting the drag factor against the speed factor, as in Figs. 6 and 7, gives the drag-speed curve corre-

FIG. 8.



lating $\overline{D}/W, = \overline{D}/L$, with V/V_0; thus exhibiting the drag, or thrust, and the efficiency L/D as functions of the speed. The equation of this curve is, by (12),

$$\overline{D}/W = (C_D/C_L \max + n)C_L \max/C_L \cdots\cdots\cdots (14')$$

or

$$y = (m\,C_D + n)x^2, \quad \cdots\cdots\cdots\cdots\cdots (14)$$

where $y = \overline{D}/W$ is the drag factor, x the speed factor, and $m = 1/C_L$ max.

Since n is known, and since at the lowest speed $V/V_0 = 1 = x$, the whole drag $\overline{D}$ and efficiency $W/\overline{D}$ are determinate for this speed; the latter absolutely, the former relatively to the weight. At sufficiently high speed, which means small incidence, C_D

is nearly constant and a minimum, making the curve (14) substantially parabolic, and of the form $y = (C_D \text{ min}/C_L \text{ max} + n)x^2$.

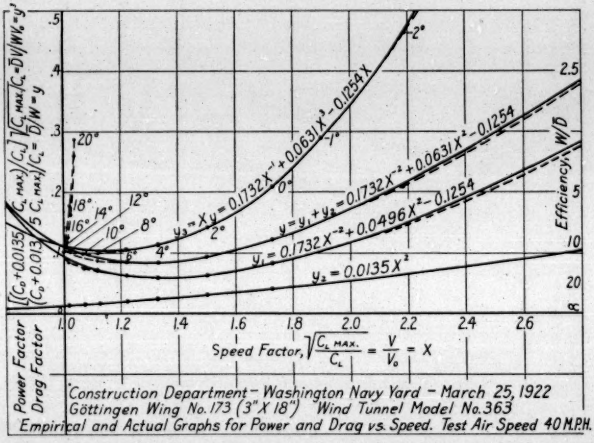
In general the drag-speed curve (13) is compounded of the two parts

$$y_1 = m C_D x^2 = C_D/C_L \quad \cdots\cdots\cdots\cdots\cdots (15)$$

$$y_2 = n x^2 = n C_L \text{ max}/C_L \quad \cdots\cdots\cdots\cdots\cdots (16)$$

due to the drags respectively of the wing group and of the body group. The latter is a parabola in x with its vertex at $x = 0 = V$.

FIG. 9.


Power Factor
Drag Factor
Speed Factor, $\sqrt{\frac{C_L \text{ MAX.}}{C_L}} = \frac{V}{V_0} = X$
Efficiency, W/D
$y_3 = X y_2 = 0.1732X^{-1} + 0.0631X^2 - 0.1254X$
$y = y_1 + y_2 = 0.1732X^{-2} + 0.0631X^2 - 0.1254$
$y_1 = 0.1732X^{-2} + 0.0496X^2 - 0.1254$
$y_2 = 0.0135X^2$
Construction Department - Washington Navy Yard - March 25, 1922
Göttingen Wing No. 173 (3" X 18") Wind Tunnel Model No. 363
Empirical and Actual Graphs for Power and Drag vs. Speed. Test Air Speed 40 M.P.H.

The former readily can be written as a simple function of x when C_D is a parabolic function of C_L, as given by (5), on noting that $C_L = C_L \text{ max}/x^2$.

Thus substituting from (5) in (15) gives

$$y_1 = (a C_L^2 + bC_L + c)/C_L \quad \cdots\cdots\cdots\cdots\cdots (17')$$

$$= a_1 x^{-2} + b + c_1 x^2 \quad \cdots\cdots\cdots\cdots\cdots (17)$$

where a_1 and c_1 are the new constant coefficients due to the indicated algebraic operation, *viz.*,

$$\left.\begin{aligned} a_1 &= a\, C_L \text{ max} \\ c_1 &= c/C_L \text{ max} \end{aligned}\right\} \quad \cdots\cdots\cdots\cdots\cdots (18)$$

One sees by (17) that y_1 is the sum of two functions, one hyper-

bolic in type, the other parabolic, as featured by the y_1 graph in Figs. 6 and 7. For a twin-camber wing $b = 0$, as previously explained.

Incidentally one notes that y_1 *versus* α is a hyperbola, since C_D/C_L is such, as seen in Fig. 1, and $y_1 = C_D/C_L$, by (15).

Adding (16) and (17) gives the drag as an explicit function of the speed, or

$$y = a_1x^{-2} + b + (n + c_1)x^2 \cdots\cdots\cdots\cdots\cdots (19)$$

$$= a_1x^{-2} + (n + c_1)x^2 \text{ for twin-camber wings} \cdots\cdots (19_1)$$

This curve tends to the hyperbolic type as x approaches zero; has a minimum for ordinary flying speeds, *i.e.*, for $x = V/V_0 > 1$; and becomes parabolic for sufficiently high speeds. It is delineated in Figs. 6 and 7, as the sum of the component curves y_1, y_2. The minimum occurs at the point where $x^4 = a_1/(n + c_1) = x_m^4$, and has the value

$$y_m = a_1x_m^{-2} + b + (n + c_1)x_m^2 = 2\sqrt{a_1(n + c_1)} + b \cdots\cdots (20)$$

This minimum drag, of course, occurs at the speed for which L/D is a maximum, as illustrated in Figs. 6 and 7.

It is noteworthy that (19_1) contains three drag terms, with W as the unit of force. The first, $a_1x^{-2} = a\ C_L$, is the pressural wing drag, and varies inversely as the square of the speed. Hence the power to overcome it varies inversely as the speed, as De Bruignac proved for a frictionless plane in 1875, and as Langley thought he proved more than a decade later. The third term, $c_1x^2 = x^3c/C_L \quad \max = C_D \quad \min/C_L$, is, at least for thin planes, the frictional wing drag; for, as seen by (18) and (5), it is the actual wing drag at zero angle of attack, for which the pressural drag is nil. To be more exact the exponent of x should be about 1.85. The separation of the drag of a thin material plane into pressural and frictional parts was first made by the writer nearly two decades ago.[1] The second term nx^2 is of course the body drag, as previously stated.

Power-speed Curve.—Multiplying (17) by $V/V_0 = x$ gives the power-speed equation,

$$y' = a_1x^{-1} + bx + (n + c_1)x^3 \cdots\cdots\cdots\cdots\cdots (21)$$

$$= a_1x^{-1} + (n + c_1)x^3 \text{ for twin-camber wings} \cdots\cdots (21_1)$$

[1] *Bull. Phil. Soc. Wash.*, vol. xiv, p. 272.

in which $y' = P/WV_0$ is the power factor, and the other symbols retain their former meaning. In Figs. 8 and 9, the power-speed curve is plotted with the drag-speed curve for an airplane having the two previously assumed wings. Obviously (21) tends to become a hyperbola for x nearing zero; a cubical parabola for x sufficiently large. At the slowest practicable speed, for which $x = 1 = V/V_0$, the drag and power factors (19) and (21) become identical.

By equating to zero the derivative of (21), or by multiplying (20) by x, one readily finds the minimum power factor. For a twin-camber wing, or any other giving $b_1 = 0$, it is

$$y'_m = a_1 x_m^{-1} + (n + c_1)x_m^3 = 1.75\sqrt[4]{a_1^3 (n + c_1)} \cdots\cdots\cdots (22)$$

at the point where $x^4 = a_1/3(n + c_1) = x_m^4$. For wings not giving $b = 0$ the value of x_m, obtained in the same way, is more cumbersome.

In (21_1) the first term is the power consumed by the "useful" wing drag, and varies inversely as the speed x; the second term nx^3 is the power for the body drag; the third term is the power for the wasteful wing drag, and for thin planes varies more nearly as $x^{2.85}$. The term bx in (21) can best be understood by reference to the definition of b in (6).

Agreement of the Algebraic and Empiric Graphs.—For the assumed twin-camber wing the actual lift and drag, or their coefficients, are perfectly represented for flying angles under 10° by algebraic equations, as shown in Fig. 1. Hence the mathematical graphs of drag and power *versus* speed, for the same range of incidence, perfectly coincide with the corresponding empiric graphs, as seen in Figs. 6 and 8. For the higher angles of attack, approaching that of maximum lift, there is a sharp departure of the lift and drag data from the linear and quadratic laws, and hence a proportionate separation of the derived curves for speed and power.

For the other aerofoil the lift and drag data obey these laws perfectly at flying incidences below 8°, but not for higher angles, as seen in Fig. 2; hence the drag and power curves show a like discrepancy in Figs. 7 and 9. For wings like the present ones, therefore, the strictly mathematical expressions for required thrust and power, at all but the highest flying incidences, are as trustworthy as those found by plotting the tabulated values.

Alternate Forms for the Graphs.—The comparison of the work quantities so far plotted, *viz.*, drag, power and speed, sometimes can be made by suitably plotting functions of them. For example, to find what value of the speed, $V/V_o = \sqrt{C_L \max/C_L}$, will require the least power, one may either note the minimum point on the graph of (13), or the minimum for (13_1), or the maximum for $C_L/(C_D + n\ C_L \max)$ *versus* $\sqrt{C_L/C_L \max}$. Again, to find what speed will require least thrust, one may either note the minimum point on the graph of (12), or the square of (12), or the maximum on the inverse curve which results from reciprocating the ordinates of (12), or the maximum on the doubly inverse curve, etc. The methods of plotting, being so manifold, can best be chosen to suit the work in hand. The present graphs directly correlate familiar quantities. But to compare the aerodynamic merits of different aerofoils it sometimes may be well to plot simpler expressions, or to compare suitable criteria which can be derived from the foregoing equations.

SUMMARY.

The main doctrines of this report may be summarized as follows:

Wing Forces and Moments.

1. The lift, drag and pitching moment of a wing of fixed size, shape and presentation, moving uniformly, are proportional to the density and square of the speed, no account of Reynold's number being taken.

2. The lift and drag increase as the square, the moment as the cube, of the linear dimensions of the wing.

3. For the more usual angles of attack α, the lift is a linear, the drag a quadratic function of α; hence the drag is a quadratic function of the lift.

4. The lift/drag is a cubic in α; the drag/lift is a hyperbola in α; hence the *drag versus* α is a hyperbola where the lift is constant.

5. The pitching moment is a linear function of the lift; and hence plots against the drag as a parabola.

6. The distance of the centre of wing pressure aft of the leading edge is approximately $l = M/L = cC_m/C_L$, c being the chord length; l plots against L as a hyperbola, against α as a hyperbola, and, with constant loading, plots against speed as a parabola.

Airplane Drag and Power.

7. The drag of an airplane consists of the "useful" or pressural wing drag, the wasteful wing drag which is mainly frictional, and the body drag. The two latter vary closely as the square of the speed; the first varies inversely as the square of the speed, if the wing load is constant. The drag-*versus*-speed graph is therefore a kind of quartic, composed of a parabola and an inverse parabola or kind of hyperbola.

8. The towline power of an airplane therefore consists of the useful part which varies inversely as the speed, and the wasteful part which increases roughly as the cube of the speed. The power-speed graph is compounded of a hyperbola and a cubical parabola.

9. Expressions are given for the minimum drag and towline power in terms of the speed of the airplane.

The Motion of a Sphere in a Rotating Liquid. G. I. TAYLOR. (*Proc. Royal Soc.*, A 715.)—There are great mathematical difficulties in the way of theoretical investigations of the motion of a sphere in a rotating liquid, but these can be overcome in the case when the sphere moves with uniform velocity along the axis of rotation of the liquid. The equations show that then there is around the sphere a sheath of liquid which does not rotate as the rest of the liquid does. This deduction from theory was confirmed by experiment. It was arranged that a cylinder of liquid was rotated about its axis. A ping-pong ball was supported by a thread passing up along the axis of the vertical cylinder. The ball took up the rotation of the liquid. Then a uniform vertical velocity was given to the ball by means of the thread. "It was found that the ball stopped rotating directly it started moving along the axis. As soon as the reel was released, so that the ball stopped moving along the axis, it quickly picked up the rotation of the rest of the system once more. To ensure success, it was found necessary also to make the ball move at a rate greater than about one diameter per revolution of the system. If the ball travelled more slowly than this it was found that it did not stop rotating and investigation of the stream-lines, with colored water, showed that a column of liquid of the same diameter as the sphere was apparently pushed along in front of the sphere.

"In the course of these experiments, it was noticed that if the sphere was stopped suddenly when half-way up the cylinder, and if there was some coloring matter present to show up the motion, a mass of liquid appeared to detach itself from the sphere, and to continue moving along the axis of rotation with the same velocity as that with which the sphere had been moving." G. F. S.

A STUDY OF THE PLASTICITY OF PAINT.*

BY

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INTRODUCTION.

It has been shown by Bingham and Hyden [1] that a colloidal solution of the polar type, such as we have when nitrocellulose is dispersed in acetone, does not possess *a definite fluidity*, as fluidities are customarily measured, for the reason that all solutions even at low concentration show the properties of plastic materials. The question now arises, Do non-polar colloids, such as clay suspended in water, require a plastic correction? The experiments of Bingham and Durham [2] and other investigators were not made under conditions which enable us to answer this question, but in view of the considerations set forth in the paper by Bingham and Hyden we must certainly regard their measurements of fluidity as *apparent fluidities* only, subject to a possible plastic correction.

Although learned very slowly, the method of attacking this problem now seems entirely obvious and simple. It is merely necessary to measure the flow of some suspensions at various shearing stresses and then observe whether the flow is directly proportional to the shearing stress or not.[3]

MATERIALS AND METHOD OF MEASUREMENT.

Ready-mixed paints are quite complex, hence we have made up suspensions for our study from Gold Seal Beckton White Lithopone and Pure Acid Refined Linseed Oil, samples of which were furnished us by the E. I. du Pont de Nemours and Company.

In a quantitative investigation it is not practicable to grind the paint between burrstones in the ordinary manner. Rubbing out by hand seemed equally out of the question, due to the difficulty of grinding an adequate sample to a uniform consistency.

* Communicated by Dr. Bingham.

[1] This JOURNAL, vol. 194, p. 731.

[2] "Fluidity and Plasticity," pp. 201–208.

[3] Cf. Bingham and Bruce, *Proc. Am. Soc. for Testing Materials*,——(1922).

We therefore used an Abbé porcelain ball-mill 22 x 24 cm. and the paint was ground for sixteen hours at a speed of 88.5 r.p.m.

Another investigation has been planned to determine the length of time which is necessary to give a constant plasticity and whether excessive grinding will affect the plasticity. There seems to be no question but that the micellian structure is being developed for a very long time after the grinding is started. In our present study of the subject, this particular question does not enter in, since we have made up a single paste and then obtained the others which we desired by thinning down with the pure oil.

The materials were used in their air-dry condition, but we have good reason to believe that small amounts of water may greatly affect the plasticity, hence in a later investigation it will be necessary to determine the effect of water and certain other substances such as soaps and free acids. The constants of the oil are as follows:

Iodine number	182.5
Saponification number	195.0
Acid number	4.13
Density 20/4°	0.9267
Refractive index at 20°	1.4810

It seems hardly practicable to make the conditions the same in grinding two different pigments, particularly when vehicles of very different fluidities are used. Even if the same mill is used with the same amount of balls of a given size and the speed is kept constant, the plasticity of the resulting paint is supposed to vary widely, hence the approach of the balls to each other will be very different and also the resulting grinding effect.

To the original sample successive additions of oil were made and mixed thoroughly by stirring for twenty minutes. The paint was then screened through a 300-mesh seive, placed in the plastometer and measured after standing for an hour in a constant temperature bath. Particularly with the thinner mixtures it was necessary to stir the paint again immediately before the measurement was made. All of the measurements were made at 25° C., except those given in Table IV, which were made at 20°. They are given in the order in which they were made.

Capillary No. 13 was the only one used in this investigation.

It had the following dimensions which had been measured by Mr. William R. Bender:

Length	5.018 cm.
Radius by mercury	0.01458 cm.
Average minor radius	0.01385 cm.
Average major radius	0.01534 cm.
Average radius calculated	0.01456 cm.

In order to obtain the yield value f, the best linear equation for the measurements on a given paint at different shearing stresses F was found by the method of averages,[4] and the intercept calculated. The efflux per second in grams is represented by M/t and the density by ρ. The mobility μ was then found as in the preceding paper by Bingham and Hyden.

TABLE I.

Plasticity of Paint Consisting of 65 per cent. Lithopone by Weight and 35 per cent. Linseed Oil.

$f=128.1$
$\mu=0.4412$
$\rho=1.885$
$t=25°$

$M/t=0.000001983\ F-0.0002839$

Shearing Stress Dynes per cm.²	Efflux g. per second—Observed.	Efflux g. per second—Calculated.	Percentage Deviation.
498.2	0.000746	0.000734	— 1.6
498.1	0.000746	0.000734	— 1.7
753.8	0.001247	0.001242	— 0.5
753.7	0.001246	0.001240	— 0.5
930.7	0.001594	0.001591	— 0.2
930.5	0.001580	0.001591	+ 0.7
1111.3	0.001943	0.001949	+ 0.3
1110.8	0.001927	0.001949	+ 1.1
1355.0	0.002438	0.002433	— 0.2
1354.8	0.002420	0.002433	+ 0.5
1525.8	0.002760	0.002772	+ 0.6
1525.4	0.002743	0.002770	+ 1.0
1698.3	0.003127	0.003113	— 0.4
1698.0	0.003136	0.003113	— 0.7
1882.5	0.003457	0.003477	+ 0.6
1885.8	0.003515	0.003485	— 0.9
			0.7 Ave.

[4] Lipka, "Graphical and Mechanical Computation," p. 127.

TABLE II.

Plasticity of Paint Consisting of 65 per cent. Lithopone by Weight and 35 per cent. Linseed Oil at 20° C.

$f=145.5$
$\mu=0.3629$
$\rho=1.891$
$t=20°C.$

$M/t=0.000001662\ F - 0.0002418$

Shearing Stress.	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
1888.7	0.002886	0.002898	+ 0.4
1892.3	0.002901	0.002903	— 0.1
1701.3	0.002594	0.002586	— 0.3
1697.1	0.002574	0.002579	+ 0.2
1494.5	0.002252	0.002243	— 0.4
1490.5	0.002245	0.002237	— 0.4
1307.3	0.001926	0.001931	+ 0.3
1310.9	0.001942	0.001938	— 0.2
1133.4	0.001642	0.001642	0.0
1132.9	0.001628	0.001642	+ 0.9
922.5	0.001295	0.001293	— 0.2
922.4	0.001288	0.001291	+ 0.2
662.2	0.000868	0.000859	— 1.1
662.0	0.000859	0.000859	0.0
			0.3 Ave.

TABLE III.

Plasticity of Paint Consisting of 62.5 per cent. Lithopone by Weight and 37.5 per cent. Linseed Oil.

$f=114.5$
$\mu=0.5257$
$\rho=1.815$
$t=25°$

$M/t=0.000002311\ F - 0.0002648$

Shearing Stress.	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
639.4	0.001211	0.001213	+ 0.2
640.9	0.001221	0.001217	— 0.3
804.5	0.001599	0.001595	— 0.2
804.2	0.001589	0.001594	+ 0.3
977.1	0.001992	0.001994	+ 0.1
976.7	0.001987	0.001993	+ 0.3
1195.9	0.002504	0.002500	— 0.2
1191.7	0.002492	0.002491	0.0
1381.7	0.002966	0.002930	— 1.2
1381.2	0.002951	0.002927	— 0.8
1547.9	0.003307	0.003313	+ 0.2
1543.6	0.003268	0.003304	+ 1.1
1864.5	0.004042	0.004046	+ 0.1
1858.0	0.003997	0.004030	+ 0.8
			0.4 Ave.

TABLE IV.

Plasticity of a Paint Consisting of 60 per cent. Lithopone by Weight and 40 per cent. Linseed Oil.

$f=107.6$
$\mu=0.617$
$\rho=1.747$
$t=25^{\circ}$

$M/t=0.000002612\ F - 0.0002811$

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
1866.0	0.004592	0.004593	0.0
1865.4	0.004586	0.004590	+ 0.1
1689.4	0.004136	0.004130	— 0.2
1688.8	0.004148	0.004130	— 0.4
1516.7	0.003619	0.003681	+ 1.7
1516.1	0.003696	0.003678	— 0.5
1326.9	0.003194	0.003185	— 0.3
1326.6	0.003190	0.003185	— 0.2
1127.9	0.002673	0.002665	— 0.3
1121.7	0.002625	0.002649	+ 0.9
896.1	0.002065	0.002059	— 0.3
895.9	0.002030	0.002059	+ 1.3
656.8	0.001440	0.001434	— 0.4
			0.6 Ave.

TABLE V.

Plasticity of a Paint Consisting of 55 per cent. Lithopone by Weight and 45 per cent. of Linseed Oil.

$f=61.5$
$\mu=0.788$
$\rho=1.930$
$t=25^{\circ}$

$M/t=0.000003110\ F - 0.0001912$

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
648.4	0.001814	0.001826	+ 0.6
648.1	0.001829	0.001825	— 0.2
924.4	0.002680	0.002684	+ 0.1
922.2	0.002689	0.002677	— 0.4
1273.9	0.003782	0.003771	— 0.3
1273.4	0.003803	0.003770	— 0.9
1567.2	0.004656	0.004684	+ 0.6
1527.9	0.004545	0.004561	+ 0.4
			0.4 Ave.

TABLE VI.

Plasticity of a Paint Consisting of 50 per cent. Lithopone by Weight and 50 per cent. of Linseed Oil.

$f=35.5$
$\mu=0.930$
$\rho=1.5225$
$t=25^{\circ}$

$M/t=0.000003440\ F - 0.0001222$

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
618.2	0.002015	0.002004	— 0.6
617.5	0.002000	0.002002	+ 0.1
808.1	0.002657	0.002658	+ 0.1
805.9	0.002643	0.002650	+ 0.3
982.0	0.003224	0.003256	+ 1.0
981.0	0.003250	0.003253	+ 0.1
1187.6	0.003981	0.003963	— 0.4
1185.1	0.003972	0.003955	— 0.4
			0.4 Ave.

TABLE VII.

Plasticity of a Paint Consisting of 45 per cent. Lithopone by Weight and 55 per cent. Linseed Oil.

$f=18.25$
$\mu=1.108$
$\rho=1.428$
$t=25^{\circ}$

$M/t=0.000003834\ F - 0.0000700$

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
377.2	0.001380	0.001377	— 0.2
377.5	0.001368	0.001376	+ 0.6
377.0	0.001367	0.001375	+ 0.6
879.5	0.003321	0.003304	— 0.5
879.2	0.003284	0.003302	+ 0.6
1296.6	0.004916	0.004905	— 0.2
1296.4	0.004907	0.004904	— 0.1
1482.2	0.005652	0.005613	— 0.7
1480.3	0.005656	0.005610	— 0.8
1656.4	0.006221	0.006286	+ 1.0
1659.7	0.006307	0.006298	— 0.1
1855.5	0.007030	0.007050	+ 0.3
1854.2	0.007036	0.007045	+ 0.1
			0.4 Ave.

TABLE VIII.

Plasticity of a Paint Consisting of 40 per cent. Lithopone by Weight and 60 per cent. of Linseed Oil.

$f=8.83$
$\mu=1.283$
$\rho=1.347$
$t=25^{\circ}$

$M/t=0.000004188\ F - 0.0000370$

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
1876.6	0.007835	0.007823	— 0.2
1876.2	0.007821	0.007803	— 0.2
1519.3	0.006327	0.006326	0.0
1518.7	0.006306	0.006324	+ 0.3
1142.7	0.004732	0.004749	+ 0.4
1142.4	0.004728	0.004748	+ 0.4
764.7	0.003153	0.003166	+ 0.4
768.1	0.003160	0.003180	+ 0.6
431.1	0.001783	0.001769	— 0.8
419.2	0.001711	0.001719	+ 0.5
423.0	0.001761	0.001735	— 1.5
			0.5 Ave.

TABLE IX.

Plasticity of a Paint Consisting of 35 per cent. Lithopone by Weight and 65 per cent. of Linseed Oil.

$f=7.68$
$\mu=1.405$
$\rho=1.277$
$t=25^{\circ}$

$M/t=0.000004347\ F - 0.00003338$

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
377.6	0.001612	0.001629	+ 1.0
381.3	0.001629	0.001645	+ 1.0
681.2	0.002903	0.002939	+ 1.2
680.8	0.002908	0.002937	+ 1.0
927.2	0.004032	0.003999	— 0.8
926.6	0.003996	0.003997	0.0
1205.4	0.005198	0.005199	0.0
1204.7	0.005186	0.005196	+ 0.2
1725.6	0.007642	0.007443	— 2.7
1730.1	0.007648	0.007463	— 2.5
			1.0 Ave.

TABLE X.

Plasticity of a Paint Consisting of 25 per cent. Lithopone by Weight and 75 per cent. of Linseed Oil.

$f=2.5$
$\mu=1.738$
$\rho=1.1535$
$t=25°$

$M/t=0.000004860\ F - 0.00001221$

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
324.1	0.001568	0.001571	+ 0.2
321.7	0.001572	0.001560	— 0.8
465.8	0.002263	0.002258	— 0.2
473.4	0.002246	0.002295	+ 2.2
823.6	0.003986	0.003992	+ 0.2
823.1	0.003997	0.003990	— 0.2
1194.6	0.005796	0.005791	— 0.1
1194.1	0.005795	0.005788	— 0.1
1482.2	0.007209	0.007185	— 0.3
1481.6	0.007183	0.007182	0.0
1748.6	0.008500	0.008476	— 0.3
1747.7	0.008446	0.008472	+ 0.3
			0.4 Ave.

TABLE XI.

Plasticity of a Paint Consisting of 15 per cent. Lithopone by Weight and 85 per cent. of Linseed Oil.

$f=3.1$
$\mu=2.029$
$\rho=1.049$
$t=25°$

$M/t=0.000005155\ F - 0.0000159$

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
366.7	0.001876	0.001875	0.0
364.5	0.001865	0.001863	— 0.1
710.8	0.003648	0.003649	0.0
716.4	0.003658	0.003678	+ 0.6
1093.5	0.005623	0.005622	0.0
1096.8	0.005632	0.005639	+ 0.1
1490.0	0.007649	0.007666	+ 0.2
1490.3	0.007659	0.007667	+ 0.1
2069.5	0.01060	0.01065	+ 0.5
2005.4	0.01041	0.01032	— 0.9
			0.2 Ave.

TABLE XII.

Fluidity of Linseed Oil.

f=0.0
ϕ=2.423
ρ=0.9259
t=25°

M/t=0.000005436 F

Shearing Stress —Dynes per cm.²	Efflux in g. per second—Observed.	Efflux in g. per second—Calculated.	Percentage Deviation.
1549.4	0.00839	0.00842	+ 0.3
1562.1	0.00851	0.00849	— 0.2
836.2	0.00652	0.00650	— 0.3
831.8	0.00647	0.00645	— 0.3
1196.2	0.004552	0.004546	— 0.1
1187.1	0.004520	0.004522	0.0
586.5	0.003174	0.003188	+ 0.4
580.5	0.003144	0.003156	+ 0.4
264.1	0.001435	0.001436	+ 0.1
256.2	0.001389	0.001393	+ 0.3
			0.2 Ave.

TABLE XIII.

Summary of Plasticity Data.

Percentage Lithopone		Density		Yield Value		Mobility	
by wt.	by vol.	Obs.	Calc.	Obs.	Calc.	Obs.	Calc.
65	28.6	1.885	1.888	128.9	128.9	0.441	0.459
62.5	26.4	1.815	1.815	114.5	113.7	0.526	0.537
60	24.4	1.747	1.748	107.6	98.6	0.617	0.616
55	20.8	1.630	1.627	61.5	68.2	0.788	0.773
50	17.7	1.5225	1.522	35.5	37.9	0.930	0.930
45	15.0	1.428	1.430	18.2	7.6	1.108	1.087
40	12.6	1.347	1.348	8.8	0.0	1.283	1.244
35	10.4	1.277	1.275	7.7	0.0	1.405	1.401
25	4.2	1.1535	1.151	2.5	0.0	1.738	1.715
15	2.8	1.049	1.048	3.1	0.0	2.029	2.029
0	0.0	0.9259	....	0.0	0.0	2.423	2.500

DISCUSSION OF RESULTS.

The Density.—We have calculated the densities of the mixtures on the assumption that there is neither expansion nor contraction in volume on mixing. The formula used is

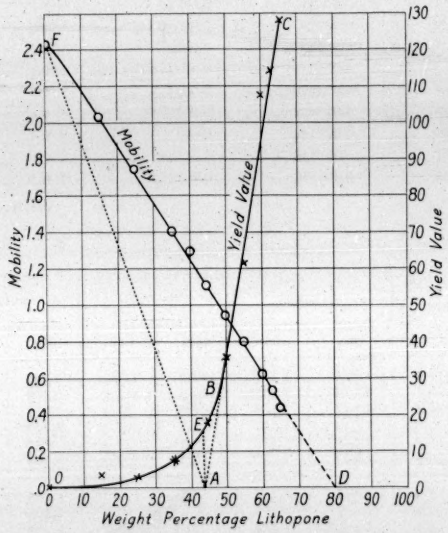
$$\rho = \frac{1}{mV_1 + nV_2}$$

where m is the fraction linseed oil of specific volume 1.080 and n is the fraction of lithopone of specific volume 0.2326. The calcu-

lated values given in the fourth column of Table XIII are in very good agreement with the observed value.

The Yield Value.—The yield values are a linear function of the weight (or volume) concentration, for concentrations over about 43 per cent. by weight, or 14 per cent. by volume, corresponding to the point *A* in Fig. 1. The equation of the curve is

FIG. 1.



The variation in the yield value and mobility obtained by dilution of a suspension of lithopone in linseed oil with more linseed oil at 25° C.

$f = 606.8\ n - 265.5$. The calculated values are given in the sixth column of Table XIII. This is similar to the relationship already found for clay suspensions.

According to earlier work [5] the point *A* is the concentration which sharply demarcates the solid from the liquid, the curve *FA* in the figure representing the fluidity curve which we would obtain with a very small shearing stress.

As a matter of fact every concentration with which we worked showed a measurable yield value, hence we have obtained a yield

[5] "Fluidity and Plasticity," p. 202.

value curve for concentrations below 43 per cent. by weight (14 per cent. by volume) *OE*, which very much resembles the yield value concentration curve given for solutions of nitrocellulose in the preceding paper. The question immediately presents itself whether even in nitrocellulose solutions the yield value concentration curve would not become linear at higher concentrations.

The reason why Kleinspehn failed to get true fluidities is because the solid particles suspended in the oil made the material no longer flow as a true fluid, so that he was working in a mixed regime, and some sort of plasticity correction was imperative. It has already been explained [6] why solid particles suspended in a liquid cause a loss of energy during shear that is not found in true fluids.

This plasticity correction finds its analogue in the viscosity correction which it is sometimes necessary to make in measurements of plasticity on account of seepage or slippage.

Had Kleinspehn determined all of his fluidities with a small shearing stress indicated by the yield value of the point *E* in the figure, he would have obtained the curve *FA* and the true concentration for the theoretical zero yield value. Had he used a smaller shearing stress the curve found would have been to the left of *FA*, and had he used a very large shearing stress, it would have approached the curve *FD*, which we obtained.

The Mobility.—The mobility turns out to be a linear function of the weight concentration. The curve is represented by the equation

$$\mu = 2.5 - 3.14n$$

and the calculated values are given in the last column of Table XIII. It appears that the mobility curve merges without discontinuity into the fluidity curve; in fact, the mobility curve may be regarded as the fluidity curve when the apparent fluidities are measured at very high shearing stresses.

The fluidity of linseed oil does not lie exactly on the mobility curve. The value was redetermined to prove that it was not an experimental error.

A zero of mobility seems to be clearly indicated at a concentration of 79.6 per cent. by weight, or 45.6 per cent. by volume.

[6] "Fluidity and Plasticity," p. 200.

It was predicted that there would be zero of mobility when there was close packing of the particles. For spheres of equal size, cubical close-packing would correspond to a concentration of 52.4 per cent. by volume. But of course we cannot assume that the particles of lithopone are equal spheres.

The Effect of Temperature on the Plasticity.—In Tables III and IV we have a little further evidence [7] of the effect of temperature, the yield value increasing from 128.1 to 145.5 and the mobility decreasing from 0.4412 to 0.3686 as the temperature is lowered from 25 to 20° C. The fluidity of linseed oil, according to Hyden, is 2.08 at 20° and 2.52 at 25°, hence the increase is 19.3 per cent. of the mean. The increase in the mobility is 19.5 per cent., which proves that the increase in mobility is entirely due to the increase in fluidity of the medium.

CONCLUSIONS.

1. From the foregoing it appears that suspensions, as well as the emulsoid type of colloids, show the properties of plastic materials even at very low concentrations of the disperse phase. The viscosity, as ordinarily measured, is not a constant but a function of the shearing stress.

2. At high concentrations, the yield value concentration relation is linear; the material is truly plastic.

3. At lower concentrations, the yield value concentration relation is not linear; the material may be said to be pseudo-plastic.

4. It seems to be possible to distinguish sharply between the plastic and the pseudo-plastic condition. With lithopone suspended in linseed oil, the transition occurs in a mixture containing 14 per cent. of lithopone by volume. This concentration may be related to important properties of the material, such as the fineness of structure, adhesion between the particles *et cet.*

5. The mobility-concentration (by weight) curve is linear, hence it seems possible by measuring the plasticity of a paint and of one other paint obtained from the first by thinning to predict the plasticity of any paint made by thinning, provided that we neglect the plasticity correction for the pseudo-plastic paints.

6. At 45.6 per cent. by volume of lithopone, the mobility would have a zero value. This concentration of zero mobility seems to be simply connected with the pore space of the material,

[7] "Fluidity and Plasticity," p. 230.

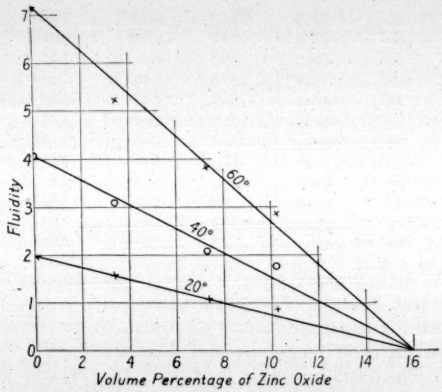
and it may have considerable significance in determining the flow of dispersions.

We desire to thank the E. I. du Pont de Nemours and Company for their interest and support which have made possible this investigation.

APPENDIX.

Mr. W. G. Kleinspehn, while working with one of the authors, endeavored to find the concentration corresponding to zero fluidity following the method which had been employed by Bingham and Durham.[8] The effort, however, was unsuccessful, for the

FIG. 2.



The apparent fluidities of suspensions of zinc oxide in linseed oil at 20°, 40°, 60°, measured by W. G. Kleinspehn.

curves from the apparent fluidities were not linear and they could not be extrapolated to zero fluidity. We believe that the difficulty was due to the relatively high viscosity of linseed oil which necessitated using a viscometer with a much wider capillary than was used by Bingham and Durham. As the paint became thicker at the higher concentrations, higher shearing stresses were necessary, which we believe tended to increase the apparent fluidity

[8] *Amer. Chem. J.*, **46**, 278 (1911).

obtained. Some of the results are given in Table XIV and in Fig. 2, and in the last column values calculated by the formula [9]

$$\varphi = \left(1 - \frac{b}{c}\right)\varphi_1$$

are given, where b is the percentage of Florence zinc oxide and c is a constant 0.16 which should represent the concentration of zero fluidity and φ_1 is the fluidity of the oil. There is poor concordance, particularly at the higher concentrations.

TABLE XIV.

The Apparent Fluidities of Suspensions of Florence Zinc Oxide in Linseed Oil as Measured in the Viscometer by W. G. Kleinspehn.

Percentage of of Pigment by Volume.	Temp.	Time—Seconds.	Pressure g. per cm.^{2}	Density $t/4°$.	Fluidity Observed.	Fluidity Calculated.
0.0	20°	505.3	124.7	0.9306	2.013	2.013
0.0	40°	407.3	75.7	0.9173	4.116	4.116
0.0	60°	484.5	36.5	0.9041	7.17	7.17
3.42	20°	345.0	233.3	1.097	1.576	1.58
3.42	40°	472.1	87.2	1.082	3.08	3.24
3.42	60°	423.0	57.3	1.069	5.24	5.64
7.32	20°	502.0	233.0	1.280	1.085	1.09
7.32	40°	545.8	111.1	1.264	2.093	2.23
7.32	60°	467.0	71.3	1.249	3.81	3.89
10.18	20°	491.4	293.3	1.463	0.594	0.73
10.18	40°	379.0	189.9	1.438	1.763	1.50
10.18	60°	486.5	90.7	1.422	2.874	2.61

Under the impression that the above values could not possibly represent true fluidities, Mr. Kleinspehn in 1919 went so far as to measure the apparent fluidity of the 10.18 per cent. paint at 20° C. at different pressures, and obtained fluidities given in Table XV which show a steady increase as the pressure was raised of some 10 per cent., the pressure increasing from 206 to 510 g. per cm.^{2} At the time no means were at hand for getting around the difficulty. By plotting the volume of flow against the shearing stress the difficulty now disappears at once. We see that the linear equation

$$V/t = 0.00002568\,F - 0.000824$$

reproduces perfectly all of the data. When the flow is zero the shearing stress is still 321 dynes per cm.,^{2} which is evidently the yield value of the material. So whereas the apparent fluidity

[9] "Fluidity and Plasticity," p. 203.

varied widely, this is because the paint had a very pronounced yield value, and when this is taken into account, the mobility, which is proportional to the slope of the above curve, becomes constant.

TABLE XV.

The Effect of Using Different Pressures upon the Apparent Fluidity of a 10.18 per cent. Suspension of Zinc Oxide by Volume in Linseed Oil at 20° C.

Time seconds.	Pressure g. per cm.²	Shearing Stress Dynes per cm.²	Apparent Fluidity.	Rate of Flow ml. per sec. Observed.	Rate of Flow Calculated.
768	206	235	0.802	0.00521	0.00521
527	288	328	0.836	0.00759	0.00761
436	340	388	0.856	0.00917	0.00915
350	418	477	0.869	0.01143	0.01143
283	510	582	0.879	0.01413	0.01413

Boric Acid as a Preservative for Canned Goods.—In principle the sterilization of foods in the canning process should be sufficient for preserving them for a reasonable time, but in practise, especially in large-scale operation, incomplete sterilization may occur and unwholesome conditions develop. One phenomenon frequently seen in spoiled canned goods is swelling of the container on account of the production of gas. These "swells," as they are called, are sometimes opened by a small perforation which allows the escape of the gas, resealed, relabelled and turned back into the market, but these practises are now probably not common. Many inquiries have been made of the Bureau of Chemistry concerning the use of boric acid as an aid in preservation. In earlier years, salicylic acid was largely used by housekeepers in home canning, though the nature of the substance was not generally known. The legislation against this has necessitated resort to other preservatives, and sodium benzoate and boric acid have been brought into notice. The Bureau of Chemistry has made a careful investigation of the action of boric acid on the organisms commonly associated with spoiled food, and also made analyses of boric acid preparations offered in the market. The work was done and the report prepared by Ruth T. Edmondson, Charles Thom and I. T. Giltner. The analyses of the powders were made by J. I. Palmore. They are sold in packages which are apparently intended to contain an ounce, but considerable difference was found in the net boric acid content of the several samples. The directions gave no warning that an excess of the material in the food might be harmful. The experiments are given fully and in detail. The results are mainly: Boric acid canning powders as sold, when used in the amount directed, con-

trol the growth of certain molds and aerobic microörganisms, but these are not responsible for spoilage in processed material. The powders had no appreciable effect on the growth of *B. botulinus*, which is a very serious contamination in some foods. The use of the powders is wasteful, since careful processing will fully preserve the materials for a reasonable time. In dealing with the moderately neutral vegetables, the use of the powder, with the inadequate heating recommended and likely to be used by the home canner, will not control the growth of the *B. botulinus*. H. L.

New Method of Helium Recovery. (*Am. Chem. Soc. News Service.*)—Satisfactory operation on a laboratory scale of a simplified and much cheaper method of recovering helium is reported through the American Chemical Society by H. Foster Bain, Director of the U. S. Bureau of Mines. In a test-run made within the last month at the cryogenic laboratory in the Interior Department Building, helium was recovered from natural gas in one operation in sufficient purity for use in dirigibles or balloons. "This development," Mr. Bain said, "indicates that very soon commercial production of helium for lighter-than-air craft may be feasible." Not only will this insure safety from fire and explosions, but it is almost certain to result in an entirely new type of airship design. The motor, for instance, could be placed inside the envelope of a helium ship if necessary. The research work leading up to this achievement was directed by the United States Helium Board, composed of Lieutenant Commander F. M. Kraus, representing the Navy; Colonel R. F. Fravel, representing the Army; Dr. R. B. Moore, chief chemist of the U. S. Bureau of Mines, and H. S. Mulliken, production engineer, alternate. The actual work of development was directed by the Board of Helium Engineers, with the following membership: M. H. Roberts, Franklin Railway Supply Company; R. C. Tolman, of the California Institute of Technology; W. L. DeBaufre, University of Nebraska; Edgar Buckingham, of the U. S. Bureau of Standards, and John W. Davis, of the U. S. Bureau of Mines. The government also had the assistance of Dr. Frederick Keyes, Massachusetts Institute of Technology, and Dr. Harvey N. Davis, Harvard.

Helium recovery, as carried on at government plants in Texas, results in a gas of about 64 per cent. purity, and necessitates a second operation to remove impurities. By the old method the flow from the natural gas wells is directed through a series of compressors which reduce the various gases in the mixture to liquid form. Methane (illuminating gas) becoming liquid at a higher temperature is taken off first. The remaining gases are then, one by one, liquefied, and helium, having an exceedingly low liquefying point, remains. The difficulty with the old method is to liquefy all of the nitrogen in the mixture.

APPLICATIONS OF HEAVISIDE EXPANSION THEOREM.*

BY

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IT was suggested to me that a few illustrations worked out in detail, showing the application of the Expansion Theorem in the solution of problems, would be helpful to bring about a better appreciation of the general utility of the theorem as a practical method for the solution of electrical problems. Acting on this suggestion, which I believe to be good, I have worked out a few examples relating to somewhat different branches of electrical engineering in order to show the wide range of applicability of the theorem.

In my paper on the derivation of the Expansion Theorem Formulæ [1] I have given two formulæ, one for constant e.m.f. and the other for sinusoidal e.m.f. as follows:

Constant e.m.f.:

$$I = \frac{E}{Z(p)_{p=0}} + \sum_{1}^{m} \frac{E\varepsilon^{p_n t}}{\frac{\partial Z(p)}{\partial p}_{p=p_n}} \cdot \qquad (1)$$

Sinusoidal e.m.f.:

$$I = \frac{E\varepsilon^{j\omega t}}{Z(p)_{p=j\omega}} - \sum_{1}^{m} \frac{E\varepsilon^{p_n t}}{(j\omega - p_n)\frac{\partial Z(p)}{\partial p}_{p=p_n}} \cdot \qquad (2)$$

In the second formula the real part only to be used.

Formula (2) is more general, it includes (1); putting $\omega = 0$ in (2) it reduces to (1).

In applying the above formulæ to the solution of problems, we may either transform the formula in any particular case to give it a form which is more or less known as derived by other methods, or what is simpler, and in some cases the only practical method, to use the formulæ directly in the form given by (1)

* Communicated by General George O. Squier, Chief Signal Officer, U.S.A., and Associate Editor of this JOURNAL.

[1] JOUR. FRANK. INST., Vol. 194, No. 6, Dec., 1922.

or (2) for numerical calculations. We shall give here illustrations of both methods.

PROBLEM 1.

Circuit of inductance L and resistance R sinusoidal e.m.f. impressed on circuit, determine the current at any time t after the e.m.f. is applied.

The circuit equation is

$$L\frac{dI}{dt} + RI = E\varepsilon^{j\omega t}, \tag{3}$$

and

$$I = \frac{E\varepsilon^{j\omega t}}{Lp + R}. \tag{4}$$

In this case

$$Z(p) = Lp + R, \tag{5}$$

a one-degree equation

$$\text{for } Z(p) = 0,$$

$$p = -\frac{R}{L}, \tag{6}$$

$$\frac{\partial Z(p)}{\partial p} = L.$$

Substituting in (2),

$$I = \frac{E\varepsilon^{j\omega t}}{Lj\omega + R} - \frac{E\varepsilon^{-\frac{R}{L}t}}{\left(j\omega + \frac{R}{L}\right)L}, \tag{7}$$

$$= \frac{E}{Lj\omega + R}\left\{\varepsilon^{j\omega t} - \varepsilon^{-\frac{R}{L}t}\right\}.$$

The real part of above equation is

$$I = \frac{E}{\sqrt{R^2 + L^2\omega^2}}\operatorname{Cos}(\omega t - \varphi) - \frac{ER}{R^2 + L^2\omega^2}\varepsilon^{-\frac{R}{L}t}, \tag{8}$$

$$\operatorname{tau}\varphi = \frac{L\omega}{R}.$$

When $\omega = 0$, constant e.m.f. the above reduces to

$$I = \frac{E}{R}\left\{1 - \varepsilon^{-\frac{R}{L}t}\right\}. \tag{9}$$

Formulæ (8) and (9) are the well-known expressions for the current rise in an inductive circuit.

PROBLEM 2.

Resistance, inductance and capacity (R, L, C) in circuit sinusoidal e.m.f. impressed.

Circuit equation:

$$L\frac{dI}{dt} + RI + \frac{1}{C}\int I\,dt = E\varepsilon^{j\omega t} \tag{10}$$

or

$$\left(Lp + R + \frac{1}{Cp}\right) I = E\varepsilon^{j\omega t}$$

$$I = \frac{E\varepsilon^{j\omega t}}{Lp + R + \frac{1}{Cp}}. \tag{11}$$

In this case

$$Z(p) = \frac{LCp^2 + RCp + 1}{Cp}, \tag{12}$$

a second-degree equation.

The roots of the above equation are

$$\left.\begin{aligned} p_1 &= -\alpha + j\beta, \\ p_2 &= -\alpha - j\beta, \end{aligned}\right\} \tag{13}$$

where

$$\alpha = \frac{R}{2L}, \quad \beta = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}. \tag{14}$$

$$\frac{\partial Z(p)}{\partial p} = L - \frac{1}{Cp^2}. \tag{15}$$

Substituting for p in (15) the values p_1 and p_2 as given by (13) we obtain

$$\left.\begin{aligned} \frac{\partial Z(p)}{\partial p}p = p_1 &= \frac{2L\beta}{\beta + j\alpha}, \\ \frac{\partial Z(p)}{\partial p}p = p_2 &= \frac{2L\beta}{\beta - j\alpha}. \end{aligned}\right\} \tag{16}$$

Substituting the above values in (2), we get the expression for the current in the circuit as follows:

$$I = \frac{E\varepsilon^{j\omega t}}{Lj\omega + R + \frac{1}{Cj\omega}} - \frac{E\varepsilon^{-(\alpha - j\beta)t}}{(j\omega + \alpha - j\beta)\frac{2L\beta}{\beta + j\alpha}} - \frac{E\varepsilon^{-(\alpha + j\beta)t}}{(j\omega + j\beta - \alpha)\frac{2L\beta}{\beta - j\alpha}}. \tag{17}$$

The first term in above expression represents the steady state, periodic component, and the other two terms the transient current component. Combining the two terms of the transient current component, we get

$$I_t = \frac{E\varepsilon^{-\alpha t}}{2L\beta}\left\{\frac{\beta+j\alpha}{j\omega-j\beta+\alpha}\varepsilon^{j\beta t}+\frac{\beta-j\alpha}{j\omega+j\beta+\alpha}\varepsilon^{-j\beta t}\right\}$$

$$=\frac{E\varepsilon^{-\alpha t}}{2L\beta}\left\{\frac{(j\beta\omega+j\beta^2-\omega\alpha+j\alpha^2)\,\varepsilon^{j\beta t}+(j\beta\omega-j\beta^2+\omega\alpha-j\alpha^2)\,\varepsilon^{-j\beta t}}{\beta^2+\alpha^2-\omega^2+2j\omega\alpha}\right\}. \quad (18)$$

Replacing

$$\varepsilon^{\pm j\beta t} \text{ by } \operatorname{Cos}\beta t \pm j \operatorname{Sin}\beta t,$$

the above will reduce to

$$I_t = \frac{E\varepsilon^{-\alpha t}}{L\beta}\left\{\frac{j\beta\omega\operatorname{Cos}\beta t-(\beta^2+\alpha^2+j\omega\alpha)\operatorname{Sin}\beta t}{\beta^2+\alpha^2-\omega^2+2j\omega\alpha}\right\}. \quad (19)$$

The real part of equation (19) is

$$I_t = \frac{E\varepsilon^{-\alpha t}}{L\beta}\left\{\frac{2\alpha\beta\omega^2\operatorname{Cos}\beta t-\left((\alpha^2+\beta^2)^2+\omega^2(\alpha^2-\beta^2)\right)\operatorname{Sin}\beta t}{(\beta^2+\alpha^2-\omega^2)^2+4\alpha^2\omega^2}\right\}. \quad (20)$$

The above may be put in a simpler form

$$I_t = \frac{E\varepsilon^{-\alpha t}}{L\beta}\frac{(\alpha^2+\beta^2)\operatorname{Cos}(\beta t+\psi)}{\sqrt{(\beta^2+\alpha^2-\omega^2)^2+4\alpha^2\omega^2}}, \quad (21)$$

$$\tan\psi = \frac{(\alpha^2+\beta^2)^2+\omega^2(\alpha^2-\beta^2)}{2\alpha\beta\omega^2}.$$

Taking the real part of the first term of the right-hand member of (17) and combining with (20), we have the complete expression for the current:

$$I = \frac{E\operatorname{Cos}(\omega t-\varphi)}{\sqrt{\left(L\omega-\frac{1}{C\omega}\right)^2+R^2}}-\frac{E\varepsilon^{-\alpha t}}{L\beta}\frac{(\alpha^2+\beta^2)\operatorname{Cos}(\beta t+\psi)}{\sqrt{(\beta^2+\alpha^2-\omega^2)^2+4\alpha^2\omega^2}} \quad (22)$$

Putting $C=\infty$ short-circuiting condenser, we have $\beta=j\alpha$ and equation (20) reduces to

$$I_t = \frac{ER\varepsilon^{-\frac{R}{L}t}}{R^2+L^2\omega^2},$$

the same as the second term of right-hand member of equation (8).

PROBLEM 3.

Coupled circuits—two inductive circuits electromagnetically coupled. The circuit equations are:

$$\left.\begin{aligned}(L_1 p + R_1) I_1 + M p I_2 &= E \varepsilon^{j\omega t},\\ (L_2 p + R_2) I_2 + M p I_1 &= 0 .\end{aligned}\right\} \tag{23}$$

Solving for I_1 and I_2 we have

$$\left.\begin{aligned}I_1 &= \frac{E (L_2 p + R_2) \varepsilon^{j\omega t}}{(L_1 L_2 - M^2) p^2 + (R_1 L_2 + R_2 L_1) p + R_1 R_2},\\ I_2 &= \frac{- E M p \varepsilon^{j\omega t}}{(L_1 L_2 - M^2) p^2 + (R_1 L_2 + R_2 L_1) p + R_1 R_2}.\end{aligned}\right\} \tag{24}$$

For the primary circuit

$$Z(p) = \frac{(L_1 L_2 - M^2) p^2 + (R_1 L_2 + R_2 L_1) p + R_1 R_2}{L_2 p + R_2} . \tag{25}$$

For the secondary circuit

$$Z(p) = - \frac{(L_1 L_2 - M^2) p^2 + (R_1 L_2 + R_2 L_1) p + R_1 R_2}{M p} . \tag{26}$$

The roots of the equation $Z(p) = 0$ are the same for (25) and (26).

$$\left.\begin{aligned}p_1 &= \frac{- (R_1 L_2 + R_2 L_1) + \sqrt{(R_1 L_2 - R_2 L_1)^2 + 4 R_1 R_2 M^2}}{2 (L_1 L_2 - M^2)},\\ p_2 &= \frac{- (R_1 L_2 + R_2 L_1) - \sqrt{(R_1 L_2 - R_2 L_1)^2 + 4 R_1 R_2 M^2}}{2 (L_1 L_2 - M^2)} .\end{aligned}\right\} \tag{27}$$

Equations (27) may be put in the following form:

$$\left.\begin{matrix}p_1\\ p_2\end{matrix}\right\} = \frac{- (\alpha_1 + \alpha_2) \pm \sqrt{(\alpha_1 - \alpha_2)^2 + 4 \alpha_1 \alpha_2 K^2}}{1 - K^2} \tag{28}$$

$$\alpha_1 = \frac{R_1}{2 L_1}, \quad \alpha_2 = \frac{R_2}{2 L_2}, \quad K^2 = \frac{M^2}{L_1 L_2} . \tag{29}$$

By (25)

$$Z(p) = L_1 \left\{ \frac{(1 - K^2) p^2 + 2 (\alpha_1 + \alpha_2) p + 4 \alpha_1 \alpha_2}{p + 2 \alpha_2} \right\} \tag{30}$$

and

$$\frac{\partial Z(p)}{\partial p} = L_1 \left\{ \frac{(1 - K^2) (p^2 + 4 \alpha_2 p) + 4 \alpha_2^2}{(p + 2 \alpha_2)^2} \right\} . \tag{31}$$

We may now substitute the values of p_1, p_2, and $\frac{\partial Z(p)}{\partial p}$ given by (28) and (31) in (2) and transform the formula into a form corresponding to the typical forms for problems of this

kind given in text-books. It is just as simple, however, if not simpler, to use formulæ (30), (31) and (2) in the present form for numerical calculations. After all, the principal value of a formula is its use for numerical computations and formula (2) is just as convenient for the purpose.

Example:

$$L_1 = 0.1 \text{ henry}, R_1 = 10 \text{ ohms}, L_2 = 0.2 \text{ henry}, R_2 = 25 \text{ ohms},$$
$$M = 0.1 \text{ henry}, \omega = 2\pi \times 60 = 377, E = 100 \text{ volts}.$$
$$\alpha_1 = 50, \alpha_2 = 62.5, K^2 = 0.5$$
$$p_1 = -64.9, p_2 = -385$$
$$\frac{\partial Z(p)}{\partial p}_{p=p_1} = 0.2664, \quad \frac{\partial Z(p)}{\partial p}_{p=p_2} = 0.0615$$
$$Z(p)_{p=j\omega} = \frac{-1161 + j1697}{25 + j75.4} = 15.7 + j20.6.$$

Substituting these values in (2)

$$I_1 = \frac{100\,\varepsilon^{j\omega t}}{15.7 + j20.6} - \frac{100\,\varepsilon^{-64.9t}}{(j377 + 64.9) \times 0.2664} - \frac{100\,\varepsilon^{-385t}}{(j377 + 385) \times 0.0615}.$$

The real part

$$I_1 = 3.86 \operatorname{Cos}(\omega t - \varphi) - 0.166\,\varepsilon^{-64.9t} - 2.16\,\varepsilon^{-385t} \text{ amperes.}$$

For constant e.m.f.

$$I_1 = \frac{100}{10} - \frac{100\,\varepsilon^{-64.9t}}{64.9 \times 0.2664} - \frac{100\,\varepsilon^{-385t}}{385 \times 0.0615}$$

$$= 10 - 5.77\,\varepsilon^{-64.9t} - 4.23\,\varepsilon^{-385t} \text{ amperes.}$$

The results for constant e.m.f. check with those obtained by a different method given as an example in my book "Calculations of Alternating Currents Problems," page 193.

To calculate the value of the current in the secondary circuit, we have by (26)

$$Z(p) = \frac{(L_1L_2 - M^2)p^2 + (R_1L_2 + R_2L_1)p + R_1R_2}{Mp}$$

$$\frac{\partial Z(p)}{\partial p} = \frac{M\{(1 - K^2)p^2 - 4\alpha_1\alpha_2\}}{K^2p^2} \qquad (32)$$

The values of p_1 and p_2 are the same as before given by (29), which combined with (32) and (2) is all the data necessary for numerical calculations.

PROBLEM 4.

The transient voltage and current on a line of distributed inductance capacity and resistance. We have for this case the well-known equation of propagation.

$$\frac{d^2V}{dx^2} = q^2V, \tag{33}$$

$$q^2 = Cp(Lp + R). \tag{34}$$

The solution of (33) is

$$V = A\varepsilon^{qx} + B\varepsilon^{-qx}. \tag{35}$$

The expression for the current at any point on the line can be readily obtained from the voltage current relation

$$(Lp + R)I = -\frac{dV}{dx},$$

and

$$I = \frac{-q}{Lp + R}\left\{A\varepsilon^{qx} - B\varepsilon^{-qx}\right\}. \tag{36}$$

Assume an e.m.f. $E\varepsilon^{j\omega t}$ impressed at one end of the line and the other end grounded, the terminal conditions in this case are:

$$\left.\begin{array}{l} x = 0,\ V = E\varepsilon^{j\omega t} \\ x = l,\ V = 0 \end{array}\right\} \tag{37}$$

The constants A and B of equation (35) are determined by (37) and substituting these values in (36) we obtain the expression for the current on the line,

$$\begin{aligned} I &= \frac{q}{Lp + R}\,\frac{E\left\{\varepsilon^{q(l-x)} + \varepsilon^{-q(l-x)}\right\}}{\varepsilon^{ql} - \varepsilon^{-ql}}\,\varepsilon^{j\omega t} \\ &= \frac{E\,\mathrm{Cosh}\,q(l-x)}{\frac{(Lp+R)}{q}\,\mathrm{Sinh}\,ql}. \end{aligned} \tag{38}$$

The generalized impedance in this case is

$$Z(p) = \frac{Lp + R}{q}\,\frac{\mathrm{Sinh}\,ql}{\mathrm{Cosh}\,q(l-x)}. \tag{39}$$

The values of q_m and p_m are determined from the equation $Z(p) = 0$, which in this case gives

$$\left.\begin{array}{l} \mathrm{Sinh}\,ql = 0 \\ ql = jn\pi,\quad n = 0, 1, 2, 3, \cdots \\ q^2 = Cp(Lp + R) = -\dfrac{n^2\pi^2}{l^2}. \end{array}\right\} \tag{40}$$

Hence

$$\left.\begin{aligned} p_n &= -\frac{R}{2L} \pm \sqrt{\frac{R^2}{4L^2} - \frac{n^2\pi^2}{l^2LC}}, \\ &= -\alpha \pm j\beta_n, \end{aligned}\right\} \tag{41}$$

where

$$\left.\begin{aligned} \alpha &= -\frac{R}{2L}, \\ \beta_n &= \sqrt{\frac{n^2\pi^2}{LCl^2} - \alpha^2}. \end{aligned}\right\} \tag{42}$$

The expression for $\frac{\partial Z(p)}{\partial p}$, for Sinh $ql = 0$, is readily obtained from (39) as follows:

$$\left.\begin{aligned} \frac{\partial Z(p)}{\partial p} &= \frac{l(Lp+R)}{q \operatorname{Cosh} qx} \frac{\partial q}{\partial p}, \\ \frac{\partial q}{\partial p} &= \frac{p+\alpha}{qv^2}, \quad \left(v^2 = \frac{1}{LC}\right) \end{aligned}\right\} \tag{43}$$

hence

$$\frac{\partial Z(p_m)}{\partial p_m} = \frac{(R + Lp_m)\, l\,(p_m + \alpha)}{q_m{}^2 v^2 \operatorname{Cosh} q_m x}. \tag{44}$$

The above may be put in the following form:

$$\frac{\partial Z(p_m)}{\partial p_m} = \frac{jl\sqrt{\frac{n^2\pi^2}{l^2} - \frac{\alpha^2}{v^2}}}{Cp_m v \operatorname{Cos}\left(\frac{n\pi x}{l}\right)} \tag{45}$$

Substituting the values of p_m and $\frac{\partial Z(p_m)}{\partial p_m}$ from (41) and (45) in (2), we get the complete expression for the current on the line.

For constant e.m.f. $\omega = 0$, substituting the values of p_m and $\frac{\partial Z(p_m)}{\partial p_m}$ in (1), we get after some straightforward simplification:

$$I = \frac{E}{Rl} + E\varepsilon^{-\alpha t}\sqrt{\frac{C}{L}}\ \Sigma\ \frac{\operatorname{Cos}\left(\frac{n\pi x}{l}\right) \operatorname{Sin}\left(\sqrt{\frac{n^2\pi^2v^2}{l^2} - \alpha^2}\, t\right)}{l\sqrt{\frac{n^2\pi^2}{l^2} - \frac{\alpha^2}{v^2}}}. \tag{46}$$

Another illustration of the application of the Expansion Theorem is given in my paper "Alternating Current Cable Telegraphy." [2]

[2] JOUR. FRANK. INST., Vol. 195, No. 2, Feb., 1923.

THE EARLIEST APPARATUS AND PROCEDURES OF PHOTOGRAPHY: CONTRIBUTIONS TO THE CENTENARY OF MODERN PHOTOGRAPHIC METHODS.*

BY

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In 1889 a semi-centennial celebration of the invention of photography was held, especially under the auspices of French photographers, the date relating to the formal announcement by Arago (before the French Academy of Sciences) of Daguerre's method of taking pictures. It is proposed to celebrate in 1923 a *centennial* anniversary, and the question at once arises as to what has become of the sixteen years that should elapse before the centenary of Daguerre's invention will occur. The answer is that while Daguerre perfected a method of taking portraits with the camera after comparatively short exposure, the first actual picture-making by means of light was done by Nicephore Niépce about 1823. It is the centennial of this procedure that France has decided to distinguish.

No such celebration can occur without raising the question of the early history of the procedure and causing disputes as to priority, but the moment the investigator begins to search the records confusion arises. What constitutes discovery or invention? Aristotle and Augustine make allusions that can be interpreted as indicating a theory of evolution, yet they are not quoted as real anticipators of Darwin and Wallace. Scattered through the writings of scientists from the thirteenth century on to the close of the seventeenth, we find more or less incidental allusions to the property of silver salts blackening in contact with organic matter, but the effect was not infrequently ascribed to the action of the air. We should not, however, deal flippantly with such mistakes, for we may note that even as late as the early part of the nineteenth century, when the natural and physical sciences had

* Presented at a joint meeting of the Sections of Physics and Chemistry and Photography and Microscopy, held Thursday, December 14, 1922.

reached a high degree of exactness, the yellow tinge seen in common flames was ascribed to the presence of water. It is now known to be due to sodium salts. The names of Albertus Magnus, Roger Bacon, Fabricius, Glauber and, of course, Leonardo da Vinci, would be mentioned in a summary of these adumbrations, but the data at hand seem to show that the first one to recognize the cause of the blackening of silver salts was Heinrich Schulze, who in 1727 demonstrated the action of light upon a mixture of chalk and silver nitrate, essentially silver carbonate. The mixture was prepared in a glass vessel, a part of which was covered by paper. On exposing to light the precipitate darkened at the unprotected places, but was not affected at the other points. By this means it was shown that the action was not due to either air or heat. It is obvious that, interesting and creditable as Schulze's experiments are, they are not photography in the sense in which the word is understood to-day. An important point is that the results could not be fixed, that is, the effect of the light could not be stopped after the action had gone as far as desired, unless the material was kept in the dark. It is also to be noted that the effects are merely copying; there is no formation of an image of an external object. All modern procedures are the results of invention and discovery along several independent lines. Whether we take instruments of research, such as the telescope and microscope, apparatus for manufacturing, such as the printing press, for transportation, such as the locomotive, or for amusement, such as the motion-picture, we will find them culminations of the labors of many workers. The motion-picture, for instance, depends upon a brilliant light source, a flexible film, a high-speed emulsion, excellent lenses, active developing and fixing materials and mechanical appliances. So in modern photography, many have had a share in the progress, and it is difficult and even invidious to give the honors to a few. The bridge built some years ago over the Susquehanna, at Havre de Grace, bore a tablet stating that it was the work of "a thousand men for four years," and similarly our modern photographic procedures may be described as the work of hundreds of investigators for several centuries.

Light has wide range of action; few substances, if any, are wholly immune, but in most cases the changes are but slowly produced and very slight. A few substances show great suscepti-

bility, the silver salts being, so far as ascertained, preëminent in this respect. In modern photography, therefore, silver dominates, and it is especially the chloride, bromide and iodide that are employed, these being conveniently included under the title "silver halides." Light produces a prompt visible effect upon silver chloride, which is darkened, but the other halides show no visible effect except upon prolonged exposure. Notwithstanding this lack of change in appearance, it is easily shown that even exceedingly brief exposures of silver bromide or iodide produce a marked change, which can be demonstrated by the precipitation of silver and some other metals—upon the parts that have been touched by the light. It has been a question whether the light acts by producing chemical decomposition or merely changes the substances physically. Considerable investigation has been carried out to determine this point. For convenience, the area of the halide affected invisibly by the light is called the "latent image." Two views as to the chemistry of the latent image are now in vogue. One is that sub-halides are formed by action of the light; the other is that a complete decomposition of a limited number of molecules takes place and that the silver thus set free is in colloidal condition. Under either theory it seems reasonable to assume that a difference of electric potential will be produced, respectively, in the parts touched and not touched by the light, and as the subsequent production of the image by development is due to the precipitation of metallic silver, a selective attraction will be the result. It is, however, not within the scope of this paper to discuss the problem to any extent. Some salts of mercury and copper are distinctly sensitive to light, although not nearly so much as the silver halides. Mercurous iodide, which is a bright yellow powder, undergoes, with moderate rapidity when exposed to a strong light, a conversion into a black powder. Presumably, this effect is due to the separation of metallic mercury in a state of fine division, in which its familiar lustre is lost. This property of mercurous iodide was studied in 1836 by Artus (*J. prak. Chem.*, 1836, viii, 63). In many cases the effect of light can be increased, in extent or rapidity, by the addition of a third substance, which may be unaffected, thus acting the part of catalyst, or may take definite part by combining with the liberated element, thus preventing a saturation or equilibrium, which would interfere with further action. It is now well known that many rays of

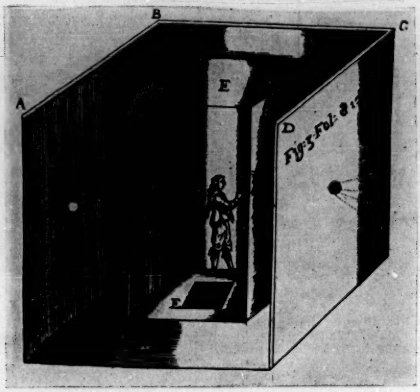
light are invisible to the human eye, but have active chemical and physical effects. Rays that are beyond the violet, which is the upper limit of the visible spectrum, have a powerful effect on silver salts.

The sensibility of silver salts to light would have had but a narrow field of application if it was not possible to project the image of any object in correct form upon a sensitized surface. That is, some optical arrangement must be employed. Schulze secured a contrast between light and darkness, but he constructed the picture—at least, we may for sake of argument call it a picture—and devised no method by which a natural object or design could be repeated on his mixture of chalk and silver nitrate. Niépce also copied designs by superposition. Other workers, especially Davy and Wedgewood in England, made experiments along these lines. They employed different materials coated with silver nitrate which blackened under the light, but such changes are too slow, even if apparatus was available, and moreover, as noted above, the prints could be preserved only in the dark.

The invention of the camera is a most important phase of the development of photography. The word goes back to a Greek word, "kamara," meaning anything with a vaulted or arched cover. It came to mean "room," especially a vaulted room, and after suffering several etymologic evolutions it has become the regular term for room in several European languages. It is the familiar instrument in all departments of photography, and probably as much mechanical ingenuity has been applied to it as to any other machine. The evolution of it from the clumsy, heavy and expensive form of Daguerre's day to the "push the button and we do the rest" of the modern amateur, would require pages to detail. Coincident with the evolution of the form of the camera itself, has gone the improvement in the lens, extending its field, improving its definition and increasing its speed.

The camera is an invention of several centuries ago. It is usually ascribed to an Italian, John Baptist della Porta, but some doubt exists as to how far he actually originated it. He developed the apparatus a great deal, and described it in a work in several volumes, which appeared during the years 1558–1589. This work was translated into several languages, an English edition appeared about a century after the original text. The title "camera obscura" refers to the fact that the room was dark

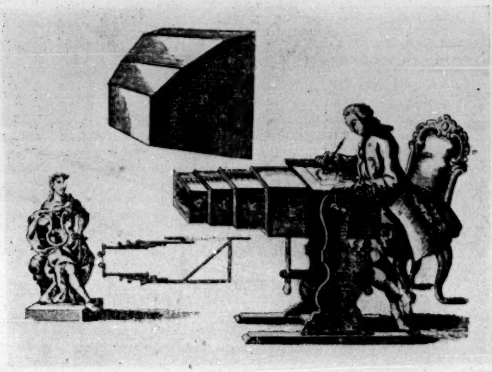
except so far as it was illuminated by the image transmitted through a lens. The modern camera in all its forms can be traced back to the apparatus della Porta described, but the formation of images is not dependent on a lens. A minute opening is capable of forming a complete picture, indeed the perspective is better than that obtained with almost any lens. To obtain a perfect image in this way, the opening should be so small as to



Kircher's camera (1671).

admit only single rays of light from all points, a condition that is not capable of being realized in practise. The opening, therefore, gives a slightly confused image, but this is no objection in landscape and architectural photography. In practise an opening about large enough to pass a small needle is made through a metal plate, quite thin at the point of perforation. Care must be taken that no bur is present; the metal must be perfectly flush on each side. Such an arrangement is usually termed a "pinhole." Pinhole pictures have been made by many workers, and according to Eder (*Geschichte der Photographie*) a precise description of such a method of projecting images of external objects was first given by Leonardo da Vinci, who stated that when a building or a landscape is brilliantly illuminated by the

sun, an inverted image can be obtained by means of a small perforation in the wall of an opposite building. He states that the opening should be very small and neat, and further that the formation of the image is akin to the formation of the image on the retina, the pupil acting as the opening. It is a remarkable anticipation of the pinhole method, but it must not be overlooked that the eye acts by means of its lens system, and that the pupil opening is too great to form a clear image on the retina. These



Early camera lucida.

discoveries of Leonardo were doomed, like many that he made, to be practically fruitless, being locked up in his writings, difficult to read and long deferred in publication. It is, therefore, not possible to say how far some of the later workers in this field owe their inventions and discoveries to accidental knowledge of Leonardo's work or made independent developments.

As noted above, pinhole pictures give better perspective than lenses, and are especially suitable for architectural subjects and some classes of landscapes. The exposure is long, being ordinarily sixty times that required with a rapid lens, so that if a given combination will give a good picture with one second exposure, a pinhole substituted for the lens will entail a one-minute period. Moving objects, unless quite slow, are not taken, so that

a pinhole camera may be employed on the side of a road over which automobiles are passing without appreciable record of these. The picture also has a softness which is not usual with those made with lenses, although modern expedients are now available by which extreme softness may be obtained by the standard cameras. These extreme degrees may be imitated to a limited extent by using a pinhole of larger diameter, but no particular advantage is gained. The minute opening is, of course, unsuited for photomicrography, in which microscopic sharpness is required.

Investigation has been carried on with great earnestness since the days of Daguerre, for his procedure made photography of wide practical value, and many methods of procedure have been devised. The daguerreotype, though highly artistic, has the disadvantage that each picture required a separate sitting, and the same was true of the ambrotype, which was made by producing a thin negative on glass and then mounting this with a black backing. The invention of the paper positive gave at once the most desired feature to picture-making, namely, the ability to produce any number of positives from one exposure. Subsequently the wet collodion process which was an early method of making glass negatives was applied to the ferrotype or "tin-type," as it was familiarly called. In this a sensitized collodion film was spread on lacquered sheet iron, and when developed and fixed gave a pleasing portrait. In this, as in the daguerreotype, each picture required a separate sitting, but this difficulty was overcome during the vogue of the method, by multiple lenses, such as four in a group, and a sliding arrangement by which four exposures could be made on one sheet, thus obtaining sixteen pictures. It is not necessary to follow the details of commercial photographic development as the principal features are well and generally known.

The introduction of desensitizers is an important and very recent feature of photography. As in all other cases, the existing methods were in a way anticipated, for many years ago it was shown that the ferrous oxalate developer diminishes materially the sensitiveness of the ordinary dry-plate emulsion, so that the development may be carried out in a brighter light than usual, but this method did not come into practical use. A couple of years ago, Lüppo-Cramer, a Münich chemist, discovered, as a result of trials of many substances, that a dyestuff known as "pheno-

safranin," had power to diminish the sensitiveness of the common emulsions, without appreciably diminishing the latent image, that is, the undeveloped impression on the plate. A solution of 1 gram to 1000 c.c. (15 grains to the 1 quart) will serve for many plates. After exposure, the plate is immersed for a couple of minutes in the solution (in darkness, of course), briefly washed, and immersed in the developer. The immersion in the dye so far abates the sensitiveness, that plates that require green light can be safely developed by the ordinary red light, and those requiring red light can be developed in yellow. The plate is

Stereoscopic drawings (supposed fourteenth century).

stained, but this can be removed by washing or by certain chemicals. In most cases the stain does interfere seriously with the use of the negative. The solution stains the hands, and it is well, therefore, to use rubber finger cots. After the plate is fixed and washed there is no danger of staining the hands. Lumière and Seyewitz made many experiments with a view of discovering substitutes for phenosafranin, but found little of importance. A yellow dye, "aurantia," was found to have marked desensitizing power, but has no special advantage. Lüppo-Cramer published the composition of the desensitizer, with the result that it was introduced into commerce in other countries under trade names, and the inventor deprived of both honor and profit of his discovery. He has since introduced two new dyes, the composition of which he has not made known, designating them simply as "pinakryptol" and "pinakryptol green," respectively.

A remarkable modification of photographic procedure is developing after fixing. Several methods have been long known, but none has special practical value. It is of considerable theoretical interest inasmuch as it has a bearing on the nature of the latent image, for by means of a weak fixing bath, all the sensitive emulsion can be removed, as far as can be judged by the eye, yet after washing thoroughly in order to get rid of the soluble salts, the image can be brought out fully by means of

Pinhole photograph.

several forms of developer, among the simplest of which is a solution containing metol, mercuric bromide and sodium sulphite. The following experiment shows the remarkable persistence of the image. A plate was exposed for several weeks in perfect darkness close to, but not in actual contact with, a plate of common amalgamated battery zinc. It was then immersed in a weak fixing bath until all trace of emulsion was removed, washed and immersed in the above-mentioned developer. The development was carried in the light. A strong image was obtained. The plate was mounted as a lantern slide, and afterward put away for a couple of years with other slides. The image gradually disappeared, and finally only a few small spots were left. The plate was again immersed in the special developer, and

in a few minutes the image appeared in good strength. It seems that the latent image may reside on gelatin as much as in the silver halide.

Finally, as an interesting instance of how difficult it is to fix definitely the time and place of scientific discovery, and to assign honors, therefore, an illustration is appended taken from the *Bulletin of the French Society of Photography* (3rd ser., 1922, ix, 206). It shows twin pictures drawn by an artist so that, when viewed in the stereoscope, a good impression of solidity is produced. The fact that the impression of solidity is given by the joint action of both eyes was known to Euclid, three centuries before the beginning of the common era and also to Galen five centuries later, but this knowledge, as was the case with much other information, appears to have been practically lost during the dark ages. Prominent workers in the early period of the revival of learning, *e.g.*, da Vinci and Porta, revived this knowledge, but it was left to Wheatstone in 1838 to devise a special instrument for producing effects of solidity from two pictures representing the image by each eye, respectively. The effect was produced by mirrors. The instrument was called a "stereoscope." Much later, Brewster devised one in which lenses are used, which became the regular form. The illustration taken from the French journal shows a stereoscopic combination that is stated to have been drawn in the fourteenth century, by an artist named Jacopo Chimenti, and is now in the Wicar Museum at Lisle. The drawings are in different ink, one red, the other black. It does not appear that there is any record of an apparatus constructed for viewing the pictures, but the matter is of great interest in the history of stereoscopy.

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Optical Constants of Sodium-potassium Alloys. RAYMOND MORGAN. (*Phys. Rev.*, Sept., 1922.)—Drude's method of obtaining the optical constants of metals was used for a series of these alloys. The index of refraction for potassium is .060 and for sodium .047. For all alloys of these two metals the index is greater than that of either of the two constituent metals. The maximum value is .137 and is for an alloy having 66 per cent. of potassium by weight. In the case of an alloy containing 82.7 per cent. of sodium, a solid, a diminution of the refractive index with rising temperature was observed. G. F. S.

STUDIES IN PHOTOGRAPHIC SENSITIVITY.*

II

THE ACTION OF HYDROGEN PEROXIDE ON PHOTOGRAPHIC GELATINO-SILVER HALIDE EMULSIONS.

BY

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INTRODUCTION.

It has been known for a long time that both the vapor and the solution of hydrogen peroxide have an action on the photographic plate somewhat similar to that of light.

W. J. Russell,[1] in 1899, was the first to give any quantitative data concerning this action. He stated that "if the liquid contains only one part of peroxide in 1,000,000 of water and the plate be exposed to its action, *i.e.*, of the vapor, for 18 hours a faint picture is produced. Bearing in mind the small amount of evaporation which takes place under these conditions and consequently the minute amount of hydrogen peroxide which comes in contact with the plate, it clearly shows the exceeding delicacy of the reaction." Even when he interposed thin sheets of gelatin, celluloid, etc., between the H_2O_2 and the plate, action took place.

The work of Russell has since been substantiated, as well as elaborated, by others who have compared more in detail the action of H_2O_2 on the photographic plate with that of light. Among the more important investigations may be mentioned that of Precht and Otsuki.[2] They showed that the action increases with the concentration of H_2O_2 up to a maximum and then decreases again. It depends upon the amount of H_2O_2 vaporized in unit time, and is, following the evaporation of a mixture of $H_2O_2 + H_2O$, greater for 3 per cent. than for 30 per cent. H_2O_2.

They found further that for equal concentrations the action increases with time of exposure up to a maximum beyond which

* Communicated by Dr. C. E. K. Mees, Director of Laboratory and Associate Editor of this JOURNAL. Published as Communication No. 158 from the Research Laboratory of the Eastman Kodak Company.

[1] *Phot. Jour.*, 23, 198, 234 (1899).

[2] *Ann. Physik.*, 4, 16, 890 (1905).

a reversal similar to solarization sets in. All their measurements were made by exposure to the vapor at 1 cm. from the surface of the liquid.

Dombrowsky [3] also carried out a very extensive investigation on the action of the vapor of H_2O_2. He believed that H_2O_2 acts in steps: (1) A relatively quick adsorption, (2) a relatively slow chemical reaction with the silver halide-gelatin. The blackening on development is the result of both.

He found that the reciprocity law

$$It = \text{const.}$$

does not hold for the action of H_2O_2 if I represents the molar concentration of H_2O_2, and t the time of exposure to the vapor at a given distance from the liquid surface.

Likewise, the Hurter and Driffield expression [4]

$$D = \gamma \operatorname{Log} \frac{It}{i}$$

was found not to hold for the action of H_2O_2 but an equation of the form

$$D = at - b,$$

i.e., linear, does hold approximately. The constants a and b depended upon the experimental conditions.

Finally, he observed an effect with long exposures similar to solarization with light.

This paper includes a very good bibliography of the action of metals and of H_2O_2 on the photographic plate.

O. and A. Dony-Henault,[5] in 1909, gave some interesting figures concerning the vaporization of $H_2O_2 - H_2O$ mixtures and the action of H_2O_2. From their experiments they concluded that the action of the H_2O_2 is not due to a radioactive phenomenon, but to chemical action of the H_2O_2 vapor. The effect followed the partial pressures of H_2O_2 vapor in mixtures of $H_2O_2 - H_2O$ which were greater in the smaller than in the higher concentrated solutions. A 12 per cent. solution in 24 hours gave off 0.88 mg. H_2O_2, whereas a 30 per cent. solution in the same time gave 0.56 mg. This agrees with the conclusion of Dombrowsky which they do not mention.

The most important value which they give is, that on 1 cm.^{2}

[3] Constantin Dombrowsky, *Inaug. Dissert.*, Leipzig, 1908, p. 68.

[4] *J. Soc. Chem. Ind.*, **9**, 455 (1890).

[5] O. and A. Dony-Henault, *Bull. Soc. Belg. Chim.*, **22**, 224 (1909).

of the plate 1.2×10^{-8} gm. H_2O_2 will produce a photographic latent image. The time of action of this quantity is not stated.

Until recently all measurements on the action of H_2O_2 had been made on the ordinary photographic plate. Svedberg [6] was the first to make any measurements of this action on the ultimate grains of the photographic emulsion (in one-grain-layer plates). The data which he gave were meagre and of diminished value because of the interference of "fog," that is, of the large percentage of grains already developable prior to the H_2O_2 or light treatment.

The object of the present investigation was to compare the action of hydrogen peroxide on the photographic emulsion with that of light. There are two aspects to this, which may be termed macroscopic and microscopic. In the first, we may measure photographic density D, which is proportional to mass of silver, determined as a function of conditions of exposure to peroxide, and ascertain if laws similar to photographic light action obtain. It has been proposed [7] to term the action of chemicals such as peroxide "photechic." [8] In the second, we have to determine, using "one-grain layers," [9] the relation between the number and size of grains made developable by peroxide (photechically) as also, the distribution of development nuclei in the grains, as recently investigated by Svedberg [10] for the action of light.

In order that inference from the second—the microscopic aspect—as to the nature of sensitiveness, developability, the latent image, etc.,[11] should be applicable to the photographic process, it requires to be shown that both macroscopically and microscopically the phenomena are quantitatively comparable. The present investigation is concerned only with the macroscopic side, and we shall show that the photechic action of hydrogen peroxide is entirely similar in effect to the photographic action of light.

[6] The. Svedberg, *Zeit. wiss Phot.*, **20**, 36 (1920).

[7] H. Blaas and B. Czermak, *Eder's Jahrb. f Phot.*, 1904, p. 274. Originally with reference to substances photographically active after illumination.

[8] From Gk. *phos* = *light*, and *ekhein* = *to hold*.

[9] The. Svedberg, *loc. cit.*; E. P. Wightman, A. P. H. Trivelli, S. E. Sheppard, J. FRANK. INST., **194**, 485 (1922).

[10] The. Svedberg, *Phot. J.*, **62**, 310 (1922) (Third Hurter and Driffield Memorial Lecture).

[11] Cf. Svedberg, *loc. cit.* We have discussed the whole problem fully in a paper in the JOURNAL OF THE FRANKLIN INSTITUTE, **194**, 485 (1922).

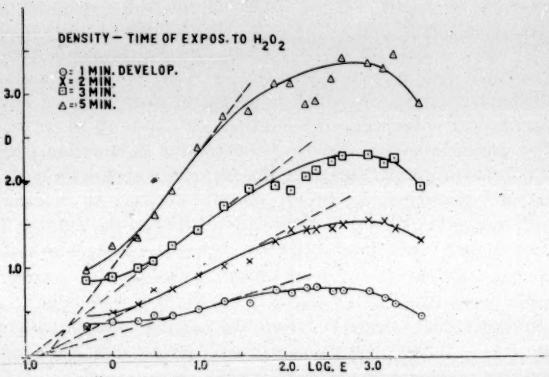
EXPERIMENTAL.

The factors of the peroxide effect which demand attention are:

1. The intensity factor, as function of concentration.
2. The time factor on exposure at constant concentration.
3. The effect of acidity or alkalinity on the peroxide effect.
4. The course of development of peroxide treated plates.
5. The behavior of different emulsions.

The actual experimental method was as follows: A number of strips about 2 × 10 cm. were cut from plates or films of the

FIG. 1.



emulsion studied. These were dipped, in pairs, back to back, in separate beakers containing about 30 c.c. each of the hydrogen peroxide solution, at a constant temperature of 20° C. After this exposure the pairs of strips were washed for one-half hour in separate beakers in rapidly running water. They were then developed in 1 : 1 pyro-soda developer,[12] stopped in 1 per cent. acetic acid solution, rinsed, fixed, washed and dried under

[12] A. Na_2SO_3 (anhyd.) ..... 64.0 grams
$NaHSO_3$ ..... 17.5 grams
Pyro ..... 20.0 grams
H_2O to ..... 1 litre
B. Na_2CO_3 (anhyd.) ..... 75 grams
KBr ..... 1 gram
H_2O to ..... 1 litre

standard conditions. Densities were measured with a Martens photometer.

A. *Time of Exposure, and Time of Development.*

The curves (see Fig. 1 plotted from data in Table I) relating density D to the logarithms of the times of exposure, for different times of development are quite similar to the well-known photographic characteristic or $H.$ and $D.$ curves. They have an "underexposed portion" or "toe," in which the density varies linearly with the exposure time; an approximately "straight line" portion, where $D \propto \log t$, although this is relatively short for the peroxide effect; an "overexposed" portion; a maximum; and a "reversal" phase. At the same time, the straight line portions, for different times of development, or the family of tangents to the inflexion points of the curves, tend to approach a common convergence point on the log t axis, comparable to the inertia of photographic sensitometry.

TABLE I.

Density-Time of Exposure.

$H_2O_2 = 0.300\ M$; $pH = 3.3$; $T = 20°$ C.

Time of Development = 1, 2, 3 and 5 Min. in 1 : 1 Pyro-soda at 20°

Rinsed in 1 per cent. Acetic Acid for 3 sec.

Fixed in Acid Hypo for 15 Min.

Plate No.	Time in Sec.	Log t	D_1	D_2	D_3	D_5
1	0.5	1.70	0.33	0.32	0.86	0.98
2	1	0	0.38	0.49	0.91	1.25
3	2	0.30	0.39	0.58	1.01	1.35
4	3	0.48	0.46	0.75	1.08	1.61
5	5	0.70	0.46	0.76	1.27	1.89
6	10	1.00	0.53	0.92	1.43	2.39
7	20	1.30	0.62	1.02	1.72	2.75
8	40	1.60	0.60	1.08	1.93	2.81
9	80	1.90	0.75	1.31	1.96	3.13
10	120	2.08	0.72	1.45	1.91	3.13
11	180	2.26	0.78	1.45	2.06	2.89
12	240	2.38	0.79	1.45	2.14	2.94
13	360	2.56	0.74	1.46	2.24	3.20
14	480	2.68	0.75	1.51	2.31	3.43
15	960	2.98	0.75	1.56	2.33	3.39
16	1440	3.16	0.67	1.55	2.23	3.32
17	1920	3.28	0.60	1.47	2.28	3.47
18	3840	3.58	0.46	1.34	1.96	2.91

B. *Effect of Increasing Concentration of Hydrogen Peroxide, the Time of Exposure Being Kept Constant.*

In these experiments—concentrations higher than 1 gm. mol. per litre were not attained, and the experiments will be pushed further.

FIG. 2.

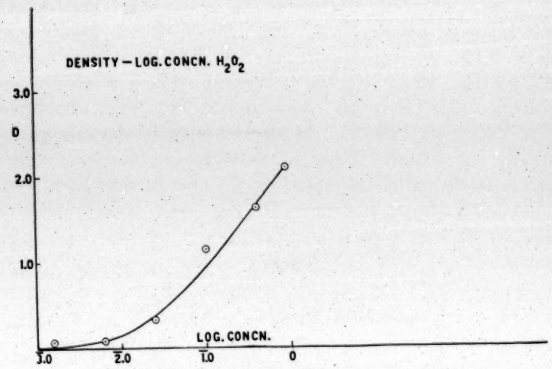


TABLE II.

Density-Concentration of H_2O_2.
Time of Exposure, 1 Min.
Time of Development, 3 Min. in 1 : 1 Pyro-soda at 20°
Rinsed in Acetic Acid and Fixed as in Table I.

Soln. No.	Conc. in Mol. / L.	Log *C*	*pH*	*Dm*	Molecules H_2O_2 per c.c.	Molecules H_2O_2 per 1 cm.^{3} x 0.01 mm.
1	0.882	1.95	3.4	1.98	5.34×10^{20}	5.34×10^{17}
2	0.400	1.60	3.7	1.63	2.42×10^{20}	2.42×10^{17}
3	0.100	1.00	4.2	1.15	6.06×10^{19}	6.06×10^{16}
4	0.025	2.40	5.6	0.33	1.52×10^{19}	1.52×10^{16}
5	0.0063	3.80	6.4	0.09	3.82×10^{18}	3.82×10^{15}
6	0.0016	3.20	7.0	0.07	9.7×10^{17}	9.7×10^{14}
7	0.0004	4.60	7.0	0.07	2.4×10^{17}	2.4×10^{14}
8	0.0001	4.00	7.0	0.06	6.1×10^{16}	6.1×10^{13}
9	0.00002	5.30	7.0	0.06	3.0×10^{16}	3.0×10^{13}

From results so far obtained, it appears that the effect of increasing concentration is similar to that of increasing light intensity. (See Fig. 2 plotted from data in Table II.)

C. *Effect of Hydrogen Ion Concentration.*—The reducing power of hydrogen peroxide is increased in alkaline, diminished in acid solution.[13] It is, therefore, of interest to note that its action on the photographic emulsion is reduced by increasing the alkalinity. It will be remembered that in these experiments the plates are dipped in the solution. The relation of the density to the Sörensen value of the solution is shown in Table III, and it is seen that over a range of *pH* values from about 4 to 7, *i.e.*, from fairly acid to the neutral point, there is very little change in the density.

TABLE III.

Density-pH.

0.175 *M* H_2O_2 at 20°

Developed 3 Min. in 1:1 Pyro at 20°

1 per cent. Acid Short Stop for 3 Sec. Fixed in Acid Hypo.

Soln. No.	*pH*	Indicator.	D_1	D_2	D_3	D_4	D_m
1	2.2	Thym. Blue	1.52	1.50	1.50	1.52	1.51
2	3.6	Br. Phen. Blue	1.52	1.58	1.39	1.43	1.48
3	3.8	Br. Phen. Blue	1.17	1.37	1.23	1.16	1.23
4	4.0	Br. Phen. Blue	1.16	1.21	1.27	1.21	1.21
5	7.2	Br. Cres. Blue	1.23	1.32	1.31	1.10	1.24
6	9.2	Thym. Blue	1.02	1.16	1.01	0.92	1.03

While not very sensitive, these results indicate that whatever chemical action of the peroxide is involved, it can hardly be an incipient reduction of the silver salt.

D. *Growth of Density and Gamma, with Time of Development.*

TABLE IV.

Density-Time of Development.

$H_2O_2 = 0.295$ *M*; *pH* = 3.3 = Temp. = 20°

Developed in 1:1 Pyro at 20°

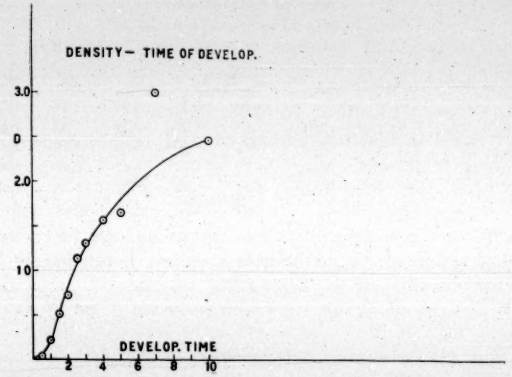
Soln. No.	Time of Development.	*Dm*	γ
1	0.5 min.	0.03	
2	1.0	0.21	0.29
3	1.5	0.51	
4	2.0	0.72	0.52
5	2.5	1.14	
6	3.0	1.31	0.77
7	4.0	1.57	
8	5.0	1.65	1.32
9	10.0	2.47	

[13] Cf. Sheppard and Mees, "Investigations," p. 148.

Of minor importance for the question at issue, but confirming the parallelism with photographic action, is the growth of density and contrast with time of development (see Figs. 3 and 4). It will be seen that the density increases rapidly at first, then gradually tends to a limit, as found for photographic exposures. Terming γ the slope of the straight line portion [14] of the "characteristic," $D = \gamma \log \frac{t}{t_0}$ this will follow a similar law in respect to time of development.

Discussion of Results.—The similarity of the action of hydrogen peroxide to that of light, as disclosed by these results, is very

FIG. 3.



striking. Before drawing definite conclusions, however, we propose to obtain further data, particularly to observe whether the photographic light "speeds" of the emulsion parallel the peroxide "speeds" or sensitivities, and further to examine the microscopic behavior in the manner being carried out for the action of light. Meanwhile, we wish to propose the following tentative hypothesis. It has been shown to be very unlikely that the peroxide is acting as a reducing agent on silver halide. The suggestion of Lüppo-Cramer [15] that its action is due to an oxidative attack on the gelatin protecting the silver halide grains does

[14] Or the tangent at the point of inflexion.

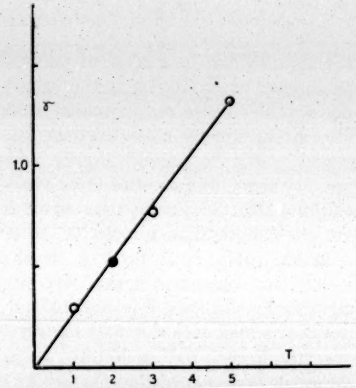
[15] *Phot. Korresp.*, 1902, p. 563.

not seem probable, in view of the great sensitiveness of the reaction. We, therefore, suggest that since hydrogen peroxide is endothermic in its formation from water

$$H_2O_2\ aq = H_2O + \tfrac{1}{2}O_2 + 25{,}650\ \text{cal.}^{16}$$

and is continually decomposing, especially in presence of catalysts, that the energy is evolved primarily as a chemi-luminescence, of short wave-length affecting the silver halide. Further, if it be supposed that this decomposition is catalyzed by the photo-sensitizing nuclei of the grains, the presence of which we have discussed

FIG. 4.



elsewhere,[17] a still closer parallelism to the photographic behavior of the *same emulsion* should obtain. If this is found, it will strengthen the view that the sensitiveness nuclei (ripening germs) in the silver halide grains, consist of colloid silver.

In connection with the quantum theory of photographic exposure [18] it is of interest to find the ratio of silver halide grains in the emulsion to the number of molecules of hydrogen peroxide in the vicinity. In the plates used the number of grains was of the order 10^9 per sq. cm., but these lie in some 10 to 30 layers, none of which covers the whole surface. Taking the concentra-

[16] Lewis and Randall, *J. Am. Chem. Soc.*, **36**, 1964 (1914).

[17] S. E. Sheppard, *Phot. J.*, **62**, 88 (1922); E. P. Wightman, A. P. H. Trivelli, and S. E. Sheppard, J. FRANK. INST., **194**, 485 (1922).

[18] L. Silberstein, *Phil. Mag.*, **44**, 257 (1922).

tions of peroxide in Table V, and assuming a layer of thickness .01 mm., as the minimum effective thickness, the number of molecules in this layer can be obtained.

TABLE V.

Concn. H_2O_2 in mol. / 1	Moles of H_2O_2 per 1 sq. cm. x .01 mm. of plate
.882	5.34×10^{17}
.4	2.42×10^{17}
.1	6.06×10^{16}
.025	1.52×10^{16}
.0063	3.82×10^{15}
.0016	9.7×10^{14} or approx. $= 10^{15}$

From this it appears that in a layer of peroxide 1 cm.$^2 \times$ .01 mm. depth the number of molecules at the lowest concentration producing a developable image on 3 minutes development is of the order 10^{15}. From kinetic considerations of diffusion, the available molecules would be actually higher. On the basis of Dr. L. Silberstein's theory of exposure these molecules would be equivalent to light darts or quanta, the effective "exposure" depending upon the chance that a molecule of peroxide collide with a silver halide grain, and form a developable nucleus. Although the data for one-grain layers are necessary before drawing any rigorous conclusions, it is evident *that the density of peroxide molecules at which only a few of the silver halide grains are affected* is very high, *viz.*, 10^{15} molecules : 10^9 grains. Consequently, it must either be assumed that the grains differ amongst themselves inherently as regards sensitivity, or, to conserve the quantum parallel, that the proportion of "active" peroxide molecules is very small.

SUMMARY.

1. The sensitometric characteristics of photographic plates exposed to hydrogen peroxide and developed are strikingly similar, both for time of exposures, time of development, and intensity (*i.e.*, concentration). Characteristic curves similar to *H.* and *D.* curves were obtained, including a period of "reversal."

2. A tentative theory of the action of hydrogen peroxide is suggested. It is supposed that the decomposition of peroxide is chemi-luminescent, short wave-length radiation being afforded at the surface of the silver halide grain, and particularly at

photosensitive nuclei. It is hoped that the reaction may be used to check the hypothesis that these nuclei consist of colloid silver.

The authors desire to express their thanks to Mr. R. F. Quirk and Mr. E. Huberth for painstaking assistance in the experimental work, and to Miss Anber J. Benedict for making the *pH* measurements.

Errata in Part I, this JOURNAL, **194** (1922).

1. p. 502, equation (b) should read $\frac{dx}{dt} = k'I.S(a-x)$, etc., instead of $\frac{dx}{dt} k'I.S\ (a-x)$.

2. p. 503, under "Equation Type B" first column, omit Roman numeral II; fourth column, lower $D = D_m(1 - e^{-k'E})$ to second row.

3. p. 518, last equation, instead of $\left\{1+(n+\mu)S_1 e^{-(\mu+n)S_1} - \text{etc.}\right\}$ read $\left\{\left[1+(n+\mu)S_1\right] e^{-(\mu+n)S_1} - \text{etc.}\right\}$

4. p. 520, first line last word should read "desensitizing" instead of "densitizing."

5. p. 520, Summary, paragraph 2, last line, read "inertia-variation" instead of "intensity-variation."

ROCHESTER, N. Y.,
Oct. 8, 1922.

Test for Acrolein.—WILMER C. POWICK, of the U. S. Bureau of Animal Industry (*Ind. Eng. Chem.*, 1923, xv, 66), has devised the following test for acrolein. Several drops of the dilute solution of acrolein are mixed with one drop of approximately 3 per cent. hydrogen peroxide. Then five c.c. of concentrated hydrochloric acid are added; and the resulting solution is shaken with five c.c. of a 1 per cent. solution of phloroglucinol in ether. A deep red color immediately appears in the aqueous layer. The pigment separates as a purple precipitate if an excess of acrolein be present. The aqueous solution of the pigment is characterized by a well-defined, fairly narrow absorption band in the yellow-green region. The absorption spectrum is identical with that of the pigment formed in the Kreis test for rancidity of fats and oils. J. S. H.

New Vitamin.—HERBERT M. EVANS and K. SCOTT BISHOP (*Science*, 1922, lvi, 650–651) have discovered a hitherto unrecognized dietary factor which is essential for the reproduction of animals. It is tentatively designated x, and is not identical with any of the vitamins hitherto known. It occurs abundantly in fresh green leaves of lettuce and is apparently present in dried alfalfa leaves.

J. S. H.

Effect of Water on Zinc Chloride.—This substance, one of the most efficient preservatives for wood, suffers much loss if the wood is exposed to water. Curiously, water causes a decomposition of the salt, removing material amounts of chlorine. Samples of preserved wood analyzed after service were found to contain zinc equivalent to 0.4 and chlorine only sufficient for 0.08. In examining treated wood, therefore, it is important to determine the chlorine as well as the zinc, since it is the chloride and not the zinc alone which gives protection. Even then some of the chlorine must be considered liable to be in the form of an insoluble compound. (Tech. Notes, Forest Products Lab.) H. L.

Use of Blue-stained Lumber.—This stain is due to a fungus in the sapwood and does not materially affect the strength of the wood. No method of killing the fungus has been found except kiln-drying. Re-surfacing will not avail when the fungus has made substantial penetration. Many uses, however, can be made of lumber so stained. (Tech. Notes, Forest Products Lab.) H. L.

On the Distribution of Radioactive Bodies in Solutions. H. LACHS and MATHILDE WERTENSTEIN. (*Physikal. Z.*, Aug. 15, 1922.)—A neutral solution of polonium was put in a burette. After a time samples were taken from the upper and from the lower parts and their radioactivity was determined. Except in the single case of the solution having been let alone one minute only there was a much higher radioactivity in the lower sample. No such difference was found when the solution was acid, but in an alkaline solution the difference between the layers was even more marked than in the neutral solution. More elaborate experiments in which samples were drawn from five levels of the liquid confirmed the previous conclusion that there is a progressive increase in radioactivity from the top of the liquid downward. Similar results were obtained with solutions containing radium alone or RaD and RaE together.

Somewhat corresponding properties of the radioactive solutions had been noted by other experimenters in respect to dialysis and Paneth had concluded that polonium in neutral solutions exists in the colloidal state. The present authors are able to fix approximately the size of the colloidal particles, but they hold that only a part of such particles can be made up of radioactive matter. It has been shown that carefully distilled water contains in a cubic centimetre some tens of thousands of foreign particles visible under the ultra-microscope. Under the influence of gravity these arrange themselves in the liquid so that they are most frequent in the lowest layers. To these the radioactive particles attach themselves. The differences in distribution are characteristic not of the radium or other radioactive substances in solution, but of water containing colloidal particles.

G. F. S.

A SURVEY OF EXISTING CRYSTAL STRUCTURE DATA.*†

BY

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Physical Chemist, Geophysical Laboratory, Carnegie Institution of Washington.

SULFIDES, SELENIDES AND TELLURIDES.

MONOSULFIDES, ETC.—Of the few crystals for which structures have been determined only zinc blende, ZnS, and alabandite, MnS, have received satisfactory treatment. The others to which assignments of structure have been made are wurtzite (ZnS), greenockite (CdS), galena (PbS) and strontium selenide.

Alabandite, MnS.—From spectrographic and powder photographic data and the results of the theory of space-groups it has been shown [84] that alabandite either has precisely the "sodium chloride arrangement" (Fig. 6) or one very close to this grouping. The possibility of such a slight variation from the sodium chloride structure must be considered because there is some crystallographic evidence for less than holohedral symmetry. The probability of such a shift in atomic positions being real does not, though, seem very great. The length of the side of the unit cube (Fig. 6) is determined as: $a = 5.214$A.U.

Zinc Blende, ZnS.—Zinc blende is one of the first crystals to have been studied with X-rays, and its structure has been investigated with both spectrometric and Laue photographic data.[85, 86, 20, 92] The atomic arrangement which is deduced from these studies gives the atoms within a unit cube 5.42A.U. on a side the coördinate positions (Fig. 9):

Zinc:	000;	$\frac{1}{2}\frac{1}{2}0$;	$\frac{1}{2}0\frac{1}{2}$;	$0\frac{1}{2}\frac{1}{2}$.
Sulfur:	$\frac{1}{4}\frac{1}{4}\frac{1}{4}$;	$\frac{3}{4}\frac{3}{4}\frac{1}{4}$;	$\frac{3}{4}\frac{1}{4}\frac{3}{4}$;	$\frac{1}{4}\frac{3}{4}\frac{3}{4}$.

A recent measurement of powder photographs [25] from this crystal gives: $a = 5.40$A.U.

Wurtzite, ZnS.—One very poor reflection [72] agrees with a "zinc oxide arrangement" (Fig. 7), but a more thorough investigation is necessary before the structure can safely be taken as established.

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* Communicated by Dr. Arthur L. Day, Director of the Geophysical Laboratory and Associate Editor of this JOURNAL.

† Continued from JOUR. FRANK. INST., Feb., 1923, 195, No. 2, p. 210.

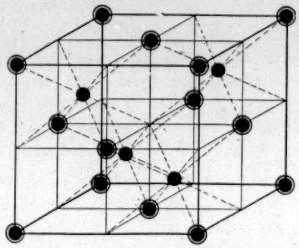
Greenockite, CdS.—A single reflection [72] appears to show that this structure also resembles that of zincite (Fig. 7).

Strontium Selenide, SrSe.—Powder photographs [88] are said to yield a "sodium chloride arrangement" (Fig. 6). The length of the side of the unit cube is given as 6.20A.U. No data have yet been published in confirmation of this assignment.

Galena, PbS.—It is reported, presumably on the basis of spectrometric measurements,[89] that this crystal has the "sodium chloride arrangement" (Fig. 6), but no data have ever appeared.

DISULFIDES, ETC.—Measurements have been made upon pyrite (FeS_2), hauerite (MnS_2) and cobaltite (CoAsS), all of

FIG. 9.



The unit cube of "zinc sulfide arrangement." According to the description in the text the sulfur atoms are shown by the black circles.

which are cubic. The first has been thoroughly studied both with spectrometric and Laue photographic measurements. The manner of arrangement of the atoms in MnS_2 has been accurately determined, though a satisfactory observation of the size of the unit cube is not available. Spectrographic data from cobaltite have given the size of the unit cell, but the atomic positions could not be established.

Pyrite, FeS_2.—Spectrometric data were early used [86] for an approximate placing of atoms. Though no treatment based upon space-group results has ever been published, there can be little doubt of the correctness of this structure. The unit cube is stated to be 5.38A.U. on an edge. The coördinate positions of the atoms within it are (Fig. 10):

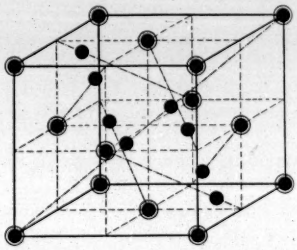
Iron:	000; $\frac{1}{2}\frac{1}{2}0$; $0\frac{1}{2}\frac{1}{2}$; $\frac{1}{2}0\frac{1}{2}$.
Sulfur:	uuu; $u+\frac{1}{2},\frac{1}{2}-u,\bar{u}$; $\bar{u},u+\frac{1}{2},\frac{1}{2}-u$; $\frac{1}{2}-u,\bar{u},u+\frac{1}{2}$; $\bar{u}\bar{u}\bar{u}$; $\frac{1}{2}-u,u+\frac{1}{2},u$; $u,\frac{1}{2}-u,u+\frac{1}{2}$; $u+\frac{1}{2},u,\frac{1}{2}-u$.

In the original assignment of structure u was made 0.4. Taking this structure as approximately right, Laue photographic data [90, 91] have been used to place the sulfur atoms with greater accuracy; thus u was found close to 0.388.

Hauerite, MnS_2.—Proceeding upon the assumption that the atomic arrangement is the same as in pyrite (Fig. 10) Laue photographic data [90, 91] have given $u = 0.400$. No measurement of the length of the side of the unit cube is recorded.

Cobaltite, CoAsS.—A spectrographic observation [93] upon a crystal of cobaltite indicates that the ratio $m/n^3 = 4$. From the

FIG. 10.



The unit cube of the "pyrite (FeS_2) arrangement." The sulfur atoms are represented by the black circles.

measurements of Laue photographs it is evident that four molecules are contained within the unit cube ($a = 5.65 \pm 0.02$A.U) and that the corresponding space-group is T^4. The coördinate positions of the atoms within the unit are thus:

Cobalt: uuu; $u + \frac{1}{2}, \frac{1}{2} - u, \bar{u}$; $\bar{u}, u + \frac{1}{2}, \frac{1}{2} - u$; $\frac{1}{2} - u, \bar{u}, u + \frac{1}{2}$.

Arsenic and sulfur have similar arrangements in v and w. The values of these parameters—u, v and w—cannot now be defined with any certainty. If, as seems probable, u has a value close to zero, the structure is analogous to that of pyrite with one of the sulfur atoms replaced by arsenic.

SUMMARY OF STRUCTURES OF "INORGANIC COMPOUNDS NOT SALTS."

The structures of the crystals of this general group which have been investigated are summarized in Table III. Alloys are not included.

TABLE III.

Crystal Structures of Inorganic Compounds not Salts.

Compound.	System of Symmetry.	Type of Arrangement.	Text Figure of Unit Cell.	Dimensions of Unit Cell.	Class of Determination.
CSi	Hexagonal	.....	.....	.....	?
H_2O	Hexagonal	.....	.....	.....	III
Cu_2O	Cubic	Cuprite	Fig. 5	$a = 4.26, 4.32$	IA
Ag_2O	Cubic	Cuprite	Fig. 5	$a = 4.768, 4.69, 4.718$	IA
CuO	Triclinic	Modified NaCl	.....	.....	IP
BeO	Hexagonal	ZnO	Fig. 7	$a = 2.696$; $c = 4.394$	IIA
MgO	Cubic	NaCl	Fig. 6	$a = 4.22$—4.18	IA
CaO	Cubic	NaCl	Fig. 6	$a = 4.74, 4.768, 4.84$	IIA
SrO	Cubic	NaCl	Fig. 6	$a = 5.104$	IIA
BaO	Cubic	NaCl	Fig. 6	$a = 5.47, 5.496$	IIA
ZnO	Hexagonal	ZnO	Fig. 7	$a = 3.22$; $c = 5.18$	IA
CdO	Cubic	NaCl	Fig. 6	$a = 4.72$	IIA
NiO	Cubic	NaCl	Fig. 6	$a = 4.14, 4.20$	IIA
SiO_2 (quartz)	Hexagonal	.....	.....	.....	IIB
TiO_2 (rutile)	Tetragonal	.....	.....	.....	IIB
TiO_2 (anatase)	Tetragonal	.....	.....	.....	IIB
$ZrSiO_4$	Tetragonal	.....	.....	.....	IIB
SnO_2	Tetragonal	.....	.....	.....	IIB
Fe_2O_3	Hexagonal	.....	.....	.....	IIB
Al_2O_3	Hexagonal	.....	.....	.....	IIB
$Mn(OH)_2$	Hexagonal	$Mn(OH)_2$	Fig. 8	$a = 3.34$; $c = 4.68$	IA
$Mg(OH)_2$	Hexagonal	$Mn(OH)_2$	Fig. 8	$a = 3.13$; $c = 4.75$	IA
MnS	Cubic	NaCl	Fig. 6	$a = 5.214$	IA
ZnS (blende)	Cubic	ZnS	Fig. 9	$a = 5.42$	IIA
ZnS (wurtzite)	Hexagonal	ZnO (?)	Fig. 7	.....	IIA?
CdS	Hexagonal	ZnO (?)	Fig. 7	.....	IIA?
SrSe	Cubic	NaCl	Fig. 6	$a = 6.20$	IIA
PbS	Cubic	NaCl(?)	Fig. 6	.....	IIA?
FeS_2 (pyrite)	Cubic	Pyrite	Fig. 10	$a = 5.38$	IIA
MnS_2 (hauerite)	Cubic	Pyrite	Fig. 10	.....	IIA
$CoAsS$	Cubic	Pyrite type	.....	$a = 5.65$	IA

HALIDES, CYANIDES, ETC.

MONOHALIDES.

This group has been more completely studied than any other. As would be expected from the difficulty of preparing crystals of appreciable size, the data are taken for the most part from powder photographs. These data have been considered from the standpoint of space-group theory so that there can be little doubt of the essential correctness of the structure assignments. This same space-group treatment is applicable to the other cubic monohalides, those of copper, silver and thallium. The only hexagonal monohalide, silver iodide, has also been given a thorough treatment. A few more complicated monohalides have been investigated with varying degrees of completeness.

Lithium Hydride, LiH.—Powder photographs[94] show four chemical molecules within a unit cube the edge of which: $a = 4.10$ A.U. They are in best agreement with a "sodium chloride arrangement" (Fig. 6) of positive lithium and negative hydrogen ions.

THE ALKALI HALIDES.—Powder photographs have been prepared from all of the alkali halides. Such data form the basis for an investigation[95, 96] of most of the members of this group of crystals that has taken account of all possible structures. Examination has also been made of various isolated compounds, but rarely have the data been presented upon which these assignments are based. The Laue photographs which have been made from a few of these crystals may be said to agree with the results of other methods of study though a thorough treatment of them by recent procedure has not been published. The summary, which is given below, of results of structure study upon these crystals shows acceptable agreement between the different studies. In several instances the determinations of absolute dimensions, however, differ by more than the natural experimental error. A study of the sizes of these crystals which is based upon analyzed material is required before these differences can be reconciled.

Lithium Fluoride, LiF.—Structure:[22] "Sodium chloride arrangement" (Fig. 6). The length of the side of the unit cube: $a = 4.14$ A.U. and $a = 4.02$ A.U.[65]

Lithium Chloride, LiCl.—Structure:[96] "Sodium chloride arrangement" (Fig. 6). The length of the side: $a = 5.17 \pm 0.02$ A.U.

Lithium Bromide, LiBr.—Structure:[96] "Sodium chloride arrangement" (Fig. 6). The length of the side: $a = 5.48 \pm 0.02$A.U.

Lithium Iodide, LiI.—Structure:[96] "Sodium chloride arrangement" (Fig. 6). The length of the side: $a = 6.06 \pm 0.02$A.U. This determination was not so satisfactory as most of the others. A couple of faint lines found upon the photographs do not agree with the structure; they are probably to be ascribed to hydration products. Likewise the calculated and observed intensities of the reflections, while not in serious disagreement with one another, are not so good as usual.

Sodium Fluoride, NaF.—Structure: "Sodium chloride arrangement" (Fig. 6). The length of the side of the unit cube: $a = 4.61 \pm 0.01$A.U.,[96] 4.68A.U.[97] and 5.62A.U.[65] The last, agreeing with that of sodium chloride and unsupported by experimental data, is undoubtedly wrong.

Sodium Chloride, NaCl.—(Fig. 6.) The length of the side of the unit cube[99, 86, 100, 98, 64] is $a = 5.628$A.U. Several diagrams[98, 64] of Laue photographs have been published.

Sodium Bromide, NaBr.—Structure: "Sodium chloride arrangement" (Fig. 6). Two determinations of the length of the side give: $a = 5.95 \pm 0.01$A.U. and $a = 6.02$A.U.[95, 97]

Sodium Iodide, NaI.—Structure: "Sodium chloride arrangement" (Fig. 6). The length[95, 97] of the side: $a = 6.47 \pm 0.01$A.U. and $a = 6.50$A.U.

Potassium Fluoride, KF.—Structure: "Sodium chloride arrangement" (Fig. 6). The length[96, 97, 65] of the side: $a = 5.36 \pm 0.01$A.U. and $a = 5.38$A.U.

Potassium Chloride, KCl.—Structure: "Sodium chloride arrangement" (Fig. 6). The length of the side[97]: $a = 6.26$A.U. Diagrams[98, 64] of Laue photographs have been published.

Potassium Bromide, KBr.[98, 64, 95, 97]—Structure: "Sodium chloride arrangement" (Fig. 6). The length of the side: $a = 6.59 \pm 0.02$A.U. and $a = 6.60$A.U.

Potassium Iodide, KI.—Structure: "Sodium chloride arrangement" (Fig. 6). The length[95, 97, 65] of the side: $a = 7.11 \pm 0.02$A.U. and $a = 7.10$A.U. A diagram of a Laue photograph has been published.[101]

Rubidium Fluoride, RbF.—In the only study that has been made,[96] the powder photographic data were not in sufficiently

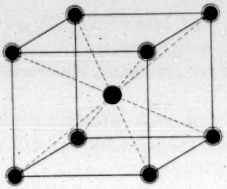
close agreement with any simple arrangement to justify an assignment of structure.

Rubidium Chloride, RbCl.—Structure: "Sodium chloride arrangement" (Fig. 6). The length[95] of the side: $a = 6.60 \pm 0.02$A.U.

Rubidium Bromide, RbBr.—Data have not been published, but this crystal undoubtedly has the "sodium chloride arrangement" (Fig. 6). The length of the side[71]: $a = 6.93$A.U.

Rubidium Iodide, RbI.—Structure: "Sodium chloride arrangement" (Fig. 6). The length[95, 102] of the side: $a = 7.36$

FIG. 11.



The unit cube of the "cæsium chloride arrangement." According to the description in the text the chlorine atom is shown by the black circle.

± 0.02A.U. and $a = 7.308$A.U. No data have been published for the second.

Cæsium Fluoride,[96] CsF.—Structure: "Sodium chloride arrangement" (Fig. 6). The length of the side: $a = 6.03 \pm 0.02$A.U.

Cæsium Chloride, CsCl.—An assignment of structure,[103] in support of which no data have been published, gives the arrangement of Fig. 11, the coördinate positions of the atoms within this unit cube being: Cæsium, 000; chlorine, $\frac{1}{2}\frac{1}{2}\frac{1}{2}$. The length of the side: $a = 4.12$A.U.

Cæsium Bromide, CsBr.—Structure: "Cæsium chloride arrangement" (Fig. 11). The length[95, 102] of side: $a = 4.30 \pm 0.01$A.U. and $a = 4.287$A.U.

Cæsium Iodide, CsI.—Structure: "Cæsium chloride arrangement" (Fig. 11). The length[95, 97] of the side: $a = 4.55 \pm 0.015$A.U. and $a = 4.58$A.U.

THE THALLOUS HALIDES.—Unpublished powder photographs[103] are said to give thallous chloride the "cæsium chloride arrangement."

Thallous Chloride, TlCl.—The length of the side of the unit cube containing a single molecule (Fig. 11): $a = 3.85$A.U.

THE CUPROUS HALIDES.—All [104] of these crystals give powder diffraction data in agreement with a "zinc sulfide arrangement" (Fig. 9). It is further shown that no other simple structure is possible and that there is no experimental evidence for a complicated one. The assurance of correctness for these structures is strengthened by the fact that both determinations of copper iodide [104, 105] have been made by methods employing the results of the theory of space-groups.

Cuprous Chloride, CuCl.—Structure: "Zinc sulfide arrangement" (Fig. 9). One determination [104] of the length of the side gives: $a = 5.49$A.U.; the other study [60] is described by saying that cuprous chloride is a diamond-cube of ions 2.32A.U. on a side. If this is understood as a "zinc sulfide arrangement" in which the distance from copper to chlorine is 2.32A.U., the length of the side of the unit cube becomes 5.36A.U. No data are published for this latter assignment.

Cuprous Bromide, CuBr.—Structure: "Zinc sulfide arrangement" (Fig. 9). One determination [104] of the length of the side gives: $a = 5.82$A.U.; the other $a = 5.75$A.U. if the results [60] are interpreted as are those of the second report on cuprous chloride.

Cuprous Iodide, CuI.—Structure: "Zinc sulfide arrangement" (Fig. 9). One of the recorded determinations was made upon artificial crystals, the other upon natural marshite which contained some silver (a previous analysis of some of the material having shown about 1.19 per cent. silver). The length of the side determined [104] from powder photographs of artificially prepared copper iodide gave $a = 6.10$A.U. in good agreement with that calculated from the density. The spacing of the marshite [105] was found to be 6.02A.U. Cuprous iodide has also been described [60] as a diamond-cube of ions 2.63A.U. on a side. This again is probably intended to mean the "zinc sulfide arrangement" in which the distance between nearest unlike atoms is 2.63A.U. If such is the case, the length of the side of the unit cube becomes 6.07A.U.

THE SILVER HALIDES.—An adequate study [105, 106] has been carried out only upon the low temperature form of silver iodide, for which both Laue photographic and powder data are available. Powder measurements have been made upon the others.

Silver iodide is particularly interesting because in the ease with which it was assigned a cubic structure, though possessed of hexagonal symmetry, it furnishes an excellent illustration of the insufficiency of unaided powder photographs and sounds a warning of the dangers arising from a disregard of available crystallographic information.

Silver Chloride, AgCl.—Two reports [107, 60] upon silver chloride give it a "sodium chloride arrangement" (Fig. 6), the length of the side of the unit cube being stated as: $a = 5.56$A.U. and 5.52A.U. In neither instance were any data presented.

Silver Bromide, AgBr.—Both determinations [107, 60] agree in giving silver bromide the same atomic arrangement as sodium chloride (Fig. 6) with the length of the side of the unit cube: $a = 5.78$A.U. No data are available for this crystal.

Silver Iodide, AgI.—According to two determinations [107, 60] based upon power data, silver iodide has a diamond-cube (meaning a zinc sulfide) arrangement with a length of side: $a = 6.53$A.U. Silver iodide is dimorphous, hexagonal below 146° C. above that cubic. It thus appears that powder photographs have been used to assign a cubic arrangement to a crystal possessed of hexagonal symmetry. This conclusion has been confirmed by the thorough treatment that has been given to this crystal with both powder and Laue photographic data,[105, 106] The Laue photographs prepared with single crystals of suitable size showed clearly a hexagonal character. The structure finally accepted is the "zinc oxide arrangement" (Fig. 7), the coördinate positions of the atoms being:

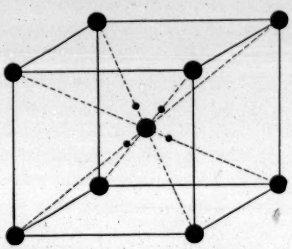
Silver: $\frac{1}{3},\frac{2}{3},0$; $\frac{2}{3},\frac{1}{3},\frac{1}{2}$. ($u$ being here taken as zero)
Iodine: $\frac{1}{3},\frac{2}{3},u$; $\frac{2}{3},\frac{1}{3},u+\frac{1}{2}$.

The length of the side of the unit prism was calculated as $a = 4.59$A.U., its height $c = 7.53$A.U. corresponding to the axial ratio $c:a = 1.639$. The data are in best agreement with a value of u close to $\frac{5}{8}$. It was further shown that all but one of the lines to be expected from the assigned cubic structure coincide with lines of the correct hexagonal arrangement. The four other lines which the hexagonal structure alone contributes to the pattern are all present but so weak that they would not be detected except upon a good film. This then is a very clear example of the dangers of trying to deduce crystal structures with unaided

powder data. As a result of a powder photograph [105] of the high temperature (cubic) form it is concluded that the structure is of great complexity. At the time of publication of this detailed treatment of silver iodide, a similar investigation was in progress in this laboratory by E. Posnjak and the writer with optical examinations by H. E. Merwin. This incomplete work had confirmed the truly hexagonal character of the salt at ordinary temperatures and yielded Laue photographs having the same general characteristics as those published.

Miersite.[105]—Material of a composition near to 4AgI.CuI has been analyzed and considered as a distinct mineral type. A

FIG. 12.



The unit cube of the atomic arrangement in the low temperature modification of ammonium chloride. In this figure the chlorine atoms are shown by the large black circles, the hydrogen atoms by the small ones. Since the position of the hydrogen atoms is indeterminable the location of these small black circles is without significance.

powder photograph showed a structure of the zinc sulfide type; consequently this mineral can be considered as a mixed crystal of silver and copper iodides.

AMMONIUM AND PHOSPHONIUM HALIDES AND SUBSTITUTED PRODUCTS.—A detailed study with both powder and Laue photographs has been made of the low temperature form of ammonium chloride. Powder data have also been obtained from the high temperature form of ammonium chloride and both forms of the bromide. Ammonium iodide has been treated with powder data and spectrometer measurements. Of the other members of this group, the simplest and probably the correct arrangement for phosphonium iodide has been deduced and a possible structure suggested for tetramethylammonium iodide.

Ammonium Chloride, NH_4Cl.—The low temperature modification of ammonium chloride is of interest because its structure

can be established with a high degree of certainty and because the symmetry of that atomic arrangement is at variance with the crystallographically assigned symmetry. On account of this special interest Laue photographic data [108] as well as powder data [109] have been used for a study [108, 110] of all possible arrangements. The atoms have the following coördinate positions within the unit cube containing a single molecule (Fig. 12):

Nitrogen:	000.
Chlorine:	$\frac{1}{2}\frac{1}{2}\frac{1}{2}$.
Hyrdogen:	uuu; $\bar{u}\bar{u}u$; $\bar{u}u\bar{u}$; $u\bar{u}\bar{u}$.

The length of the side of this unit has been found [109] to be: $a = 3.859$A.U.; the positions of the hydrogen atoms is indeterminable.

Powder photographic [109] data are said to give a "sodium chloride arrangement" of the atoms of the high temperature form of ammonium chloride. The length of the side of the unit cube containing four chemical molecules is stated to be 6.533A.U. at 250° C. The correct structure for this crystal may not be so simple as this.[111] If the hydrogen atoms have positions whose symmetry conforms to that of the crystal as a whole, and if there are four chemical molecules within the unit cube, the crystal symmetry can no longer be holohedral cubic. Two arrangements of the nitrogen and chlorine atoms become possible, one (I) derived from the space-groups T^1 or T_d^1, the other (II) from the space-group T^4. The coördinate positions in these two cases are

(I) uuu; $\bar{u}\bar{u}u$; $\bar{u}u\bar{u}$, $u\bar{u}\bar{u}$, where u has a different value for N and I.

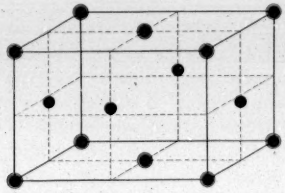
(II) uuu; $u+\frac{1}{2},\frac{1}{2}-u,\bar{u}$; $\bar{u},u+\frac{1}{2},\frac{1}{2}-u$; $\frac{1}{2}-u,\bar{u},u+\frac{1}{2}$, u being different for N and I. Since the powder data are in substantial agreement with the "sodium chloride arrangement," it seems necessary that u_N and u_I have such values as will make these arrangements approach closely to this grouping. In (I) it is accomplished by making u_N and u_I near to $\frac{1}{4}$ and $\frac{3}{4}$; in (II) they have values close to 0 and $\frac{1}{2}$. Two possible arrangements containing thirty-two molecules within the unit also can be made to approach the sodium chloride structure. There are various ways of arranging the hydrogen atoms. It will be seen that no more than an approximation to the correct atomic arrangement can now be furnished. The same is true of the high temperature

form of ammonium bromide and of the ordinary modification of ammonium iodide.

Ammonium Bromide, NH_4Br.—Low temperature form:[109] Powder photographic data from the form stable at room temperature give the body-centred structure characteristic of the ordinary form of ammonium chloride (Fig. 12). The length of the side of this unit cube containing one chemical molecule is stated as $a = 3.988$A.U.

High temperature modification:[109] At 250° C. the powder data are said to agree with a "sodium chloride arrangement," the length of the side at this temperature being: $a = 6.90$A.U.

FIG. 13.



The arrangement of the atoms within the unit tetragonal prism that has been assigned to crystals of phosphonium iodide. The iodine atoms are represented by black circles. The hydrogen atoms are not shown because the manner of their arrangement could not be definitely established.

For the reasons outlined under the corresponding form of ammonium chloride this determination is only approximate.

Ammonium Iodide, NH_4I.—Ammonium iodide stable at room temperature corresponds to the high temperature form of the other ammonium halides. Two studies have been made on the structure of this crystal, one with spectrometric measurements,[112] the other with powder data.[109] They agree in assigning to it a "sodium chloride arrangement," the length of the side of the unit being: $a = 7.20$A.U. and $a = 7.199$A.U. As already pointed out, this structure is only approximately established.

Phosphonium Iodide, PH_4I.—Crystals of phosphonium iodide possess tetragonal symmetry. It has been shown [113] that spectrographic and Laue photographic data agree with the following atomic arrangement of the phosphorus and iodine atoms:

Phosphorus:	000; $\frac{1}{2}\frac{1}{2}0$.
Iodine:	$0\frac{1}{2}u$; $\frac{1}{2}0\bar{u}$.

The dimensions of this unit tetragonal prism are found to be:

$a = 6.34$A.U., $c = 4.62$A.U. This arrangement is shown in Fig. 13. The hydrogen atoms can have various distributions about the phosphorus atom. The results of the theory of space-groups indicate that there is no simpler arrangement which will fit these data.

Tetramethylammonium Iodide, $N(CH_3)_4I$.—Only spectrometric observations [112] have been made upon these crystals which likewise have tetragonal symmetry. In the original assignment of structure four carbon atoms were arranged in a tetrahedron which did not contain the nitrogen of the substituted ammonium radical. This arrangement was chemically so improbable that other possible arrangements have been investigated.[111] As a result it was decided that the corresponding space-group is D_{4h} and a structure was presented which placed the nitrogen atoms at the centres of tetrahedrons of carbon atoms. The single application of spectrometric measurements to so complicated a crystal cannot be taken as entirely satisfactory. Furthermore, even if the space-group assignment is correct the several arrangements that arise have not all been eliminated. For these reasons more work, both of an experimental and theoretical character, must be carried out before the atomic arrangement will be established.

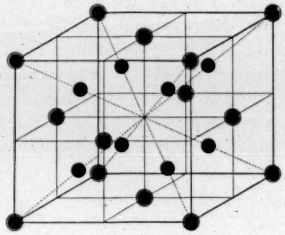
MONOCYANIDES.—*Potassium cyanide* is the only crystal of this group whose structure has been investigated by X-ray methods. In a preliminary announcement spectrometer and spectrometer powder observations [114] are believed to show an arrangement similar to that prevailing in sodium chloride. This assignment is substantiated by a detailed treatment [115] based upon spectrographic and Laue photographic data. It is pointed out that if there are four chemical molecules within the unit as the data indicate, then the symmetry must be either tetrahedral or tetartohedral with an atomic arrangement built upon the same special cases that have just been discussed for the high temperature form of ammonium chloride. If the structure contains thirty-two molecules within the unit cell its symmetry can be holohedral with one of the arrangements mentioned as possibilities for ammonium chloride and treated in detail for magnesium oxide.[68] The centres of the cyanide groups and of the potassium atoms must approach the "sodium chloride arrangement." The two determinations place the length of the side of the unit cell

containing four chemical molecules as: $a = 6.54$A.U. and $a = 6.55$A.U.

DIHALIDES.—Two fluorides of metals, CaF_2 and BaF_2, have been investigated. Besides these cadmium iodide and the dihydrochloride of hydrazine have been studied.

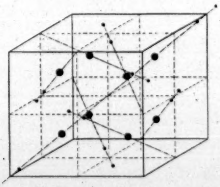
Fluorite, CaF_2.—The structure assigned to this crystal has been based upon spectrometric measurements.[86] Laue photo-

FIG. 14.



The unit cube of the "fluorite arrangement." The eight fluorine atoms within this unit are represented by black circles.

FIG. 15.



The arrangement of atoms within the unit cube of hydrazine hydrochloride ($N_2H_6Cl_2$). In this modified pyrite grouping the nitrogen atoms are shown by small, the chlorine atoms by large circles. The hydrogen atoms have not been given.

graphs [98] also have been prepared. Four chemical molecules are contained within the unit cube (Fig. 14) with atoms in the following coördinate positions:

Calcium: 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$.

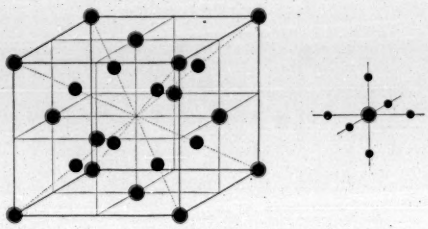
Fluorine: $\frac{1}{4}\frac{1}{4}\frac{1}{4}$; $\frac{3}{4}\frac{3}{4}\frac{1}{4}$; $\frac{3}{4}\frac{1}{4}\frac{3}{4}$; $\frac{1}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{1}{4}$; $\frac{1}{4}\frac{3}{4}\frac{1}{4}$; $\frac{1}{4}\frac{1}{4}\frac{3}{4}$.

The length of the side of this unit cube has been variously stated as [26, 25, 60] 5.40A.U., 5.452A.U. ± 0.2 per cent., 5.478A.U. ± 0.2 per cent., 5.455A.U. ± 0.1 per cent. and 5.49A.U. All of these except the first are based upon powder measurements.

Barium Fluoride, BaF_2.—Powder photographic data[60] are said to give the "calcium fluoride arrangement" (Fig. 14), though no data have been published. The length of the side of the unit cube is given as: $a = 6.20$A.U.

Cadmium Iodide, CdI_2.—This trigonal crystal has been studied[116] with spectrographic and Laue photographic data. It is shown that these data agree with a hexagonal unit containing one chemical molecule. The length of the side of such a unit

FIG. 16.



The arrangement of atoms within the unit cube of crystals of the hexammonates of the nickel halides and of crystals isomorphous with ammonium chloroplatinate. In the unit cell shown in this figure nickel atoms and platinum, or isomorphous, atoms are represented by ringed circles. Six nitrogen atoms are grouped about each nickel atom and six chlorine atoms about each platinum atom after the manner of the side figure. This little figure is drawn in parallel orientation to the large unit cell.

prism is $a = 4.24$A.U., its height $c = 6.84$A.U. The coördinate positions of the atoms (Fig. 8) are:

Cadmium: 000.
Iodine: $\frac{1}{3},\frac{2}{3},u$; $\frac{2}{3},\frac{1}{3},\bar{u}$.

The parameter u for iodine is found to be close to 0.75. Except for a different value of u this is the pyrochroite arrangement.

Hydrazine Dihydrochloride, $N_2H_6Cl_2$.—The structure of this cubic crystal has been studied[117] with the aid of spectrographic and Laue photographic data. It is shown that in the unit cube which is 7.89A.U. on a side and contains four chemical molecules, the atoms must have the arrangement expressed by the following coördinates (Fig. 15):

Chlorine atoms: uuu; $u+\frac{1}{2},\frac{1}{2}-u,\bar{u}$; $\bar{u},u+\frac{1}{2},\frac{1}{2}-u$; $\frac{1}{2}-u,\bar{u},u+\frac{1}{2}$; $\bar{u}\bar{u}\bar{u}$; $\frac{1}{2}-u,u+\frac{1}{2},u$; $u,\frac{1}{2}-u,u+\frac{1}{2}$; $u+\frac{1}{2},u,\frac{1}{2}-u$.

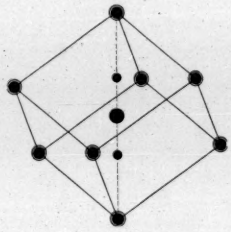
Nitrogen atoms: a similar arrangement in v.

Hydrogen atoms: the twenty-four generally equivalent positions of the space-group T_h^6.

The parameter u for chlorine is 0.27+; the most probable value of the similar parameter v for the nitrogen atoms is taken to be around 0.04.

AMMONATES OF THE DIHALIDES.—The three hexammonates of the nickel halides ($NiX_2.6NH_3$) are the only members of this group which have been investigated. Their structures [118] have been studied with spectrographic and Laue photographic data.

FIG. 17.



The arrangement of the atoms within the unit rhombohedron of cæsium dichloriodide. No attempt is made to show the true shape of this rhombohedron. The iodine atoms are indicated by large, the chlorine atoms by small black circles.

The arrangement of the atoms within the unit cube which contains four molecules (Fig. 16) is the following:

Nickel:	000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$.
Halogen:	$\frac{1}{4}\frac{1}{4}\frac{1}{4}$; $\frac{3}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{1}{4}$; $\frac{3}{4}\frac{3}{4}\frac{1}{4}$; $\frac{3}{4}\frac{1}{4}\frac{3}{4}$; $\frac{1}{4}\frac{3}{4}\frac{3}{4}$; $\frac{1}{4}\frac{3}{4}\frac{1}{4}$; $\frac{1}{4}\frac{1}{4}\frac{3}{4}$.
Nitrogen:	$u00$; $\bar{u}00$; $u\frac{1}{2}\frac{1}{2}$; $\bar{u}\frac{1}{2}\frac{1}{2}$;
	$0u0$; $0\bar{u}0$; $\frac{1}{2}u\frac{1}{2}$; $\frac{1}{2}\bar{u}\frac{1}{2}$;
	$00u$; $00\bar{u}$; $\frac{1}{2}\frac{1}{2}u$; $\frac{1}{2}\frac{1}{2}\bar{u}$;
	$u+\frac{1}{2},\frac{1}{2},0$; $\frac{1}{2}-u,\frac{1}{2},0$; $\frac{1}{2},u+\frac{1}{2},0$; $\frac{1}{2},\frac{1}{2}-u,0$;
	$u+\frac{1}{2},0,\frac{1}{2}$; $\frac{1}{2}-u,0,\frac{1}{2}$; $0,u+\frac{1}{2},\frac{1}{2}$; $0,\frac{1}{2}-u,\frac{1}{2}$;
	$\frac{1}{2},0,u+\frac{1}{2}$; $\frac{1}{2},0,\frac{1}{2}-u$; $0,\frac{1}{2},u+\frac{1}{2}$; $0,\frac{1}{2},\frac{1}{2}-u$.

Hydrogen: there are several different arrangements possible depending upon the symmetry assumed for these crystals but they all agree in permitting three of the hydrogen atoms to be associated with each nitrogen atom to form an ammonia group.

Nickel Chloride Hexammonate, $NiCl_2.6NH_3$.—The length of the side [118] of the unit cube is: $a = 10.09$A.U. It is shown that u for nitrogen has a value between 0.227 and 0.245. A simple announcement,[119] without any data, agrees with these results.

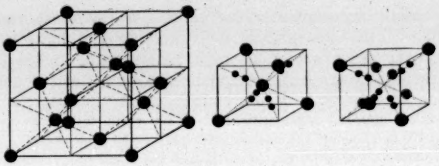
Nickel Bromide Hexammonate, $NiBr_2.6NH_3$.—The length of the side [119] of the unit cube is: $a = 10.48$A.U. No estimation was made of u.

Nickel Iodide Hexammonate, $NiI_2.6NH_3$.—The length of the side of the [119] unit cube is: $a = 11.01$A.U. The nitrogen atoms could not be so accurately placed as in the chloride, but it was shown that u must lie between 0.20 and 0.25, probably near to 0.24.

POLYHALIDES.—Diffraction measurements have been recorded upon cæsium dichloriodide and potassium triiodide.

Cæsium Dichloriodide, $CsCl_2I$.—This crystal is crystallographically reported as dimorphous, rhombohedral and orthorhombic. Repeated trials produced only the rhombohedral modification and twins which simulated orthorhombic symmetry. Both spectrographic and Laue photographic data [120] were used to assign a structure, but no detailed use was made of the results of the theory of space-groups. Nevertheless, it is probable that the structure is correct. The coördinate positions within the unit rhombohedron (Fig. 17) are the following:

FIG. 18.



The arrangement of the atoms within the unit cube of crystals of potassium zinc cyanide. The position of the eight zinc atoms is shown in the large cube. The two sub-units indicate the positions of the other atoms within alternate little cubes of the unit cell. Because they could not be distinguished both the carbon and nitrogen atoms are shown by little black circles.

Cæsium:	000;	or $\frac{1}{2}\frac{1}{2}\frac{1}{2}$.
Iodine:	$\frac{1}{2}\frac{1}{2}\frac{1}{2}$;	or 000.
Chlorine:	uuu;	$\bar{u}\bar{u}\bar{u}$.

The angle between the axes of this unit is 70°42′; its length of side: $a = 5.46$A.U. The parameter u lies between 0.312 and 0.317. Unfortunately it was impossible to decide between the alternative arrangements of the cæsium and iodine atoms because of their probably similar scattering powers.

Potassium Triiodide, KI_3.—A cubic structure has been given [121] to this crystal by a modified spectrometer method. In view of its apparently well-established monoclinic symmetry, a further consideration of this work is not justified, particularly in the absence of experimental data.

(To be concluded.)

Selective Reflection of λ 2536 by Mercury Vapor. R. W. WOOD. (*Phil. Mag.*, Dec., 1922.)—"In earlier papers it was shown that there appear to be two types of selective reflection of radiation which is very nearly in synchronism with the free period of the mercury molecule at the 2536 absorption line. One type is due to the abnormally low value of the refractive index of the vapor on the short wave-length side of the line. The change of refractive index at the boundary quartz-Hg vapor is greater than the change for a boundary quartz-vacuum, since the refractive index is less than unity, consequently we have strong reflexion for radiations immediately adjacent to the absorption line on the short wave-length side. The high value of the refractive index of the vapor for radiations slightly greater than that of the absorption line, makes the change of index at the boundary small, consequently the reflection for these radiations is very feeble. This was shown by reflecting the light of $\lambda = 2536$ from a quartz arc operated at high temperature (2536 broad and strongly reversed) from the inner surface of a flat prismatic quartz plate which was sealed to a quartz bulb containing mercury vapor at a pressure of several atmospheres. The reflected light was photographed with a quartz spectrograph, and only the short wave-length half of the reversed 2536 line was found on the plate." An additional experiment with a more homogeneous source of light confirmed the result, but it seemed desirable to try it with an even more homogeneous light. The light from a water-cooled quartz mercury arc was sent to a quartz monochromator. From this a strong beam of 2536 light fell on a mercury resonance lamp at room temperature. The monochromatic 2536 light from this impinged on the surface of a prismatic quartz plate which formed the end of a quartz tube containing mercury vapor. From the plate the light was reflected to a photographic plate. The tube was used cold or heated to 400° C. "The image reflected from the plate was much denser in the case of the exposure with the bulb hot." "The reflecting power of the plate when backed by dense mercury vapor (density corresponding to 400°) was between 3.5 and 4 times as great as the normal reflecting power of the quartz for the wave-length in question." G. F. S.

Anomalies in the Thermal Expansion of Glass. P. LAFON. (*Comptes Rendus.*)—These anomalies came to light in the study of enamels. The differential method of Chevenard was used in which a comparison is made of the expansion of the specimen of glass with that of a rod of steel of the same length. At about 500° C. a smaller dilation of the glass than at lower temperatures shows itself. When the glass cools down this anomaly does not appear. At about 600° C. glass ceases to expand and at higher temperatures contracts. This is a reversible phenomenon. It is difficult to make the author's statements agree with his curves.

G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

RECOMMENDED MINIMUM REQUIREMENTS FOR SMALL DWELLING CONSTRUCTION.[1]

INVESTIGATIONS by a Congressional Committee during 1919 and 1920 disclosed that existing building laws, through variations and inconsistencies of their provisions and through unduly restrictive or expensive requirements, were operating to prevent needed activity in the building industry. That these conditions might be remedied, a committee of experienced architects and engineers was organized by Secretary Hoover, to investigate building practice and code requirements and to prepare standard building regulations based on the latest and best information, which might be recommended to cities and states adopting or revising building codes.

The first report of this committee presents recommendations for the construction of one- and two-family dwellings having exterior walls of solid or hollow masonry, concrete, and frame, the latter including veneer and stucco surfaces.

In order that its recommendations might have sound bases of information and opinion, the committee obtained the coöperation of nearly one hundred architectural and engineering societies, builders' exchanges, and industrial organizations producing building materials. Special questions also were referred to large groups of individual engineers, architects, building officials, to the Bureau of Standards, and to others whose experience qualified them to discuss such subjects. Tentative recommendations were drafted and submitted widely for discussion and criticism by those interested in the work, and the final report reflects the influence of this consideration.

The committee recommends that building codes permit 8-inch solid brick and 6-inch solid concrete walls for 2½- and 3-story dwellings accommodating not more than two families each; that 8-inch hollow building tile, hollow concrete block, or hollow walls of brick (all rolok) shall not exceed 20 feet in height to the

* Communicated by the Director.

[1] Abstract of a report by the Building Code Committee of the Department of Commerce, published for the committee by the Bureau of Standards.

gables; and that frame construction be limited to 2½ stories. Metal lath and plaster on wood studs properly firestopped is approved for party and division walls, but at least every alternate wall in row houses must be 8-inch solid brick or concrete or 12-inch hollow building tile, concrete block, or hollow wall of brick.

Requirements for quality of hollow masonry units agree fairly well with present practice, but those for brick are somewhat below the medium grade established by the American Society for Testing Materials. The report recommends revised working stresses for timber used in dwellings, based on investigations of the U. S. Forest Products Laboratory. Live loads to be required as bases for design are 40 pounds per square foot for floors of wood, and 30 for those of monolithic type, or of solid or ribbed slabs. Foundation walls of brick are required to be 12 inches thick for excavated enclosures, and similar concrete walls shall be as thick as the walls they support but not less than 8 inches. Special hollow building tile 12 inches thick is permitted for foundation walls of frame buildings. Detailed recommendations are given for firestopping and chimney construction, also for treatment of built-in garages.

The recommended requirements are followed by a lengthy appendix containing explanatory material and much educational matter for the guidance of builders, with particular reference to the merits of 8-inch and 12-inch masonry walls, use of lumber, stucco construction, plastering, and other important subjects.

Protection of Wood from Moisture. (Tech. Notes, Forest Products Laboratory.)—The porosity of wood makes it susceptible to marked changes by changes in moisture content. Investigations were made to determine the best protecting coatings. Linseed oil though highly valued was found to be of little use. The best coating is the aluminum leaf which was developed in the Forest Products Laboratory as a coating for airplane propellers, but this can be applied only to large unbroken surfaces. Asphalt and pitch paints are efficient, but the color is often objectionable. No way has yet been found to apply over these paints lighter colored materials. Cellulose lacquers have some advantages. For temporary protection vaselin smeared over varnish or a heavy coat of paraffin is satisfactory. These cannot be used on surfaces subject to wear. H. L.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

QUANTUM THEORY OF PHOTOGRAPHIC EXPOSURE. II.[1]

By L. Silberstein and A. P. H. Trivelli.

An account is given of some further experimental tests of the theory proposed in the first paper by Silberstein (*Phil. Mag.*, 1922, **44**, p. 257), and some new formulæ are deduced from the fundamental one given in that paper, especially a formula which takes care of the finite breadth of a size-class of grains. Svedberg and Andersson's independent work is mentioned as coroborating the theory. The principles of clumps as units used in the previous paper is defended. Finally, two tables of experimental results obtained in the laboratory, and of theoretical values are given which show, on the whole, an excellent agreement between the facts and the light dart or light quantum theory of photographic exposure.

ASTRONOMICAL PHOTOGRAPHIC PHOTOMETRY AND THE PURKINJE EFFECT. II.[2]

By F. E. Ross.

The four methods in use for the photographic photometry of stars are outlined and the principles underlying each are pointed out. The turbidity method depends on the increase of size of image with intensity. The Greenwich formula connecting the diameter of the image with the magnitude of the star is shown to fail for images less than 50μ in diameter and a new formula which holds for all cases is suggested: $\sqrt{(d+h)} = a + b \log I$, where a, b, and h are constants. On the assumption that the growth of the image is due to diffuse scattering and reflection of light formulæ for the intensity of this light at any distance from the edge are deduced and section of images are given which show both theoretical and actual equiluminous surfaces. However, it is found by experiment that the rate of growth or turbidity is not constant but increases with the intensity, for instance, from

* Communicated by the Director.

[1] Communication No. 149 from the Research Laboratory of the Eastman Kodak Company and published in *Phil. Mag.*, November, 1922, p. 956.

[2] Communication No. 150 from the Research Laboratory of the Eastman Kodak Company and published in *Astrophys. J.*, December, 1922, p. 345.

9 to 12μ when the intensity is multiplied three hundred fold. This effect is of importance in accurate measurements, since, if it is not allowed for, deduced relative magnitudes will vary with the time of exposure. Data are also given showing marked variations of turbidity with the kind of plate, and with the telescope used, but if the optical system is well corrected the optical turbidity should be negligible. The probable error of this method is about $0.^{M}1$ for very sharp images but may be reduced considerably by using plates of greater turbidity and with small inherent irregularity. In the densitometric method which involves the measurement of out-of-focus images, the probable error is small except that due to inherent plate irregularities, so the more these are reduced the greater will be the relative accuracy of this method. The variation of turbidity with wave-length, the photographic Purkinje effect, is of great importance. The results obtained are reviewed, but because of the complexity of the effect no general conclusions can as yet be given. An explanation is suggested for Abney's discovery that for some plates the least gradation is for the wave-length of maximum sensitivity.

Transmission of some photographic plates to white, blue, green, and red light is given. While Bloch and Renwick have found that the absorption is not exponential, for very thin films the law (Bouguer's) may hold, at least approximately.

Photographic turbidity for spectrum lines is found to be the same as for circular images of the same width.

ON THE SPECTRUM OF NEUTRAL HELIUM.[3]

By L. Silberstein.

A QUANTUM theory of the spectrum lines of neutral helium is given, based on the assumption that there is *no appreciable interaction* between the two electrons revolving around the nucleus. The spectrum formula yielded by this assumption is a superposition of two Balmerian ones and is shown to represent with sufficient accuracy over eighty (out of the 110) spectrum lines of neutral helium, hitherto unaccounted for theoretically. The probability of the agreement being merely fortuitous is estimated to be exceedingly small. Possible applications of the principle (of no interaction between interatomic electrons) to other atoms, especially to lithium, is hinted at.

[3] Communication No. 156 from the Research Laboratory of the Eastman Kodak Company and published in *Astrophys. J.*, September, 1922, p. 119.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE ODOROUS CONSTITUENTS OF APPLES. II. EVIDENCE OF THE PRESENCE OF GERANIOL.[1]

By Frederick B. Power and Victor K. Chesnut.

[ABSTRACT.]

AN examination of McIntosh apples has confirmed the results of a previous investigation that the odorous constituents of the apple consist chiefly of amyl esters, and it has also afforded further information respecting the substance which imparts to some apples a distinctly rose-like odor. Although the proportion of this substance, even in the McIntosh apple, is extremely small, it has nevertheless been possible to show with some degree of certainty that it consists of the aliphatic terpene alcohol geraniol, $C_{10}H_{18}O$.

The evidence for this conclusion may be adduced from the fact that by the hydrolysis of the esters of the apple a product was obtained which possessed, in addition to the odor of amyl alcohol, a rose-like fragrance, and that by the oxidation of this product it yielded, besides valeric acid, a substance which had the characteristic odor and other properties of the aldehyde citral. At the same time the formation in very small quantities of the further oxidation products of geraniol or citral, which are acetone and levulinic acid, was indicated. It is probable that geraniol, either in the free state or in the form of esters, is contained in varying quantities in all varieties of the apple, although to the greatest extent in those which possess its distinctive odor.

SIGNIFICANCE OF WHEAT HAIRS IN MICROSCOPICAL EXAMINATION OF FLOUR.[2]

By George L. Keenan.

[ABSTRACT.]

DATA obtained on experimental samples of flour indicate the possibility of making an interesting classification based on the wheat-hair count alone. Of course, the number of hairs or hair fragments from the brush of the wheat grain might differ mate-

* Communicated by the Chief of the Bureau.

[1] Published in *J. Amer. Chem. Soc.*, **44** (December, 1922): 2938.

[2] Issued as *U. S. Dept. Agr. Bul. 1130*, Jan. 26, 1923.

rially, according to the variety of wheat used and the milling operations employed. Nevertheless, an examination of a large number of samples representing a great variety of milling practices indicates that flours made from purified middlings material show a low hair count, while flours containing lower-grade mill stocks show a higher hair count.

CANNED SPINACH AS A SOURCE OF BOTULISM.[3]

By Ruth B. Edmondson, Charles Thom and L. T. Giltner.

[ABSTRACT.]

THE Microbiological Laboratory of the Bureau of Chemistry obtained for study 653 cans of the pack of spinach responsible for the outbreak of botulism at Kendallville, Indiana. Cans found free from evidence of spoilage, as determined by inspection, were free from evidence of bacterial activity, as determined by culture. Cans showing swell carried active contaminations with bacteria or were pronounced examples of chemical corrosion. In so far as the samples received from commercial sources were concerned, inspection by persons familiar with canned spinach proved to be a safe basis for passing or condemning these samples. Exactly the same results were obtained in the investigation of a number of separate brands in 1921.

In cans inoculated for experimental purposes, resealed and incubated, individual discordant examples were encountered. Three out of sixty-four cans reached a stage of toxin formation sufficient to kill guinea-pigs before gas or odor or both had developed sufficiently to make possible their removal by inspection. Among large numbers of cans handled under widely different storage conditions, the occurrence of an occasional can in which toxicity has reached the danger point before gas or swell is detectable is clearly a possibility in dealing with spinach. Hence careful inspection before opening should be followed by actual recooking of this product as it comes from the can.

Incubation under observation at the factory is recommended, with such precautions in identifying the lot or batch as will insure the detection of undercooked lots of cans from any cause.

[3] Published in *Am. Food Journal*, **18** (January, 1923) : 33.

NOTES FROM THE U. S. BUREAU OF MINES.*

MESOTHORIUM.

By Herman Schlundt.

AMONG the thirty-odd radioactive elements, mesothorium, the first product of thorium, ranks next to radium in importance. Like radium, its disintegration products emit the three types of radiation that are characteristic of radioactive substances and that are known as alpha, beta, and gamma rays. Mesothorium decays at least 250 times faster than radium, and hence in the pure state its activity, weight for weight, would greatly exceed that of radium. Although itself rayless, its first product, which is rapidly formed after mesothorium has been separated, gives a powerful beta and gamma radiation; the alpha radiation of freshly prepared radium attains a maximum within a month, whereas that of mesothorium increases comparatively slowly, and reaches its high point during the fifth year after separation. Mesothorium preparations therefore must be "aged" before their full alpha-ray effect is realized in luminous products.

In the radium series one member, radium C, is mainly responsible for the gamma radiation. In the mesothorium series two members—the first product, mesothorium 2, and the final radioactive member, thorium D—emit gamma rays, those from thorium D being the most penetrating rays known. The maximum gamma activity is attained during the fourth year after separation, and its value is approximately 2.5 times that due to the mesothorium 2 present at the time. Consequently, during the first years of separation, notwithstanding the comparatively rapid decay of mesothorium, its preparations maintain a higher gamma-ray activity than an equivalent quantity of radium. Mesothorium may thus serve as a substitute for radium, both in luminous compounds of radium and for therapeutic purposes.

Further details, based on experimental work by the writer in laboratories of the U. S. Bureau of Mines, the Welsbach Company, and the University of Missouri, covering a period of several years, are presented in Technical Paper 265.

* Communicated by the Director.

COAL ANALYSES FROM TWENTY-FIVE LABORATORIES COMPARED.

By A. C. Fieldner, H. M. Cooper, and F. D. Osgood.

THE Bureau of Mines has recently conducted a study of results obtained in analyzing similar samples of coal and coke by twenty-five laboratories throughout the country, in comparison with results obtained in the bureau's coal laboratory at Pittsburgh. The purpose of this work was primarily to obtain a comparison of the methods of coal analysis used by the laboratories of the American Gas Association. Standard samples were prepared in the Bureau of Mines' coal laboratory at Pittsburgh, and portions sent to each laboratory, and to twelve commercial laboratories not affiliated with the association.

The results obtained indicate a closer application of the A.S.T.M. methods outlined in the *Gas Chemists' Handbook* than in previous comparisons. It is essential that all of the laboratories of the Gas Association, as well as other coal laboratories, use the standard methods in their coal work to ensure accurate analysis of the fuel. Attention is called to the following points:

1. Dry air must be circulated through the moisture oven at a sufficient rate to change the volume of the oven three to four times per minute.

2. The best results are obtained for the determination of volatile matter when a 10 c.c. capsule type crucible with a well-fitting cover is used. The electric furnace is superior to the Meker burner for consistent work.

3. The use of open burners is likely to give high results with manufactured gas in the sulphur determination. Sulphur determined from bomb washing will invariably run low, varying in proportion to the amount of sulphur present.

4. More attention should be given to the proper application of corrections for acidity, radiation, and sulphur in the calorimeter determination. The calorimeter bomb should have an inner surface of platinum, gold, porcelain enamel, or other material not attacked by nitric or sulphuric acids or other products of combustion.

Nickel linings should not be used if results checking within A.S.T.M. limits are desired. Further details are given in Serial 2432 of the bureau.

METALLURGICAL POSSIBILITIES OF THE DESCLOIZITE ORES AT GOODSPRINGS, NEVADA.

By H. A. Doerner.

FOR the past three or four years attention has been attracted to the deposits of lead vanadate in the Goodsprings, Nevada, district. Some ore running as high as 9 per cent. V_2O_5 has been produced, but most of it runs from 0.5 to 3 per cent. Only a little ore, and that of the richer sort, has been shipped.

It has been estimated that the district is capable of producing twenty-five tons per day of ore averaging from 2 per cent. to 3 per cent. V_2O_5. Since ore of that grade and character will not stand the cost of shipment or of chemical refining, a concentrating mill is essential to any plan for the exploitation of the deposits.

Experiments on table concentration of the ore indicate that ordinary classification and tabling of the ore and treatment of the slimes on a special canvas table will extract at least 70 per cent. of the lead and vanadium content and yield a concentrate containing 10 per cent. V_2O_5 and over 30 per cent. Pb.

No practical method, either mechanical or chemical, was found which would reduce the loss of metals in the slimes below 15 per cent. of the total amount.

The 10 per cent. V_2O_5 concentrate will stand the costs of shipment and the extraction of the lead and vanadium, but on account of its unusual nature, there may be difficulty in finding a satisfactory market. If such is the case, the concentrate may be profitably refined by smelting to remove the lead and reduction of the vanadium bearing slag to ferro alloy by means of silicon; or the lead may be separated by a reducing caustic fusion and the vanadium leached from the slag and precipitated as vanadic acid. The latter method is to be preferred on account of the uniformly high extraction and the high-grade product. Further details are given in a recent report issued by the bureau.

EFFECT OF CARTRIDGE DIAMETER ON THE STRENGTH AND SENSITIVENESS OF CERTAIN HIGH EXPLOSIVES.

By Spencer P. Howell and J. E. Crawshaw.

ONE of the most important problems in mental mining, tunneling or quarrying, is the most economical method of bringing down the ore or rock. The two factors having great influence in determining this are drilling and blasting costs.

The bureau's attention has been called to the lack of definite data on the effect of cartridge diameter on the strength and sensitiveness of high explosives. This information is especially valuable to the user of explosives as it assists him in determining what diameter of borehole is most economical.

The Bureau of Mines, in coöperation with the Institute of Makers of Explosives, has carried out a series of tests to show the effect of cartridge diameter on the strength and sensitiveness of certain high explosives.

The explosives chosen for the tests are those very extensively used in metal mining, tunneling and quarrying, namely, 40 per cent. strength L. F. gelatin dynamite, 60 per cent. strength L. F. gelatin dynamite and 40 per cent. strength ammonia dynamite.

The tests carried out have shown conclusively,

(1) That both the rate of detonation and sensitiveness to explosion by influence increase with the increase in diameter of cartridge.

(2) That gelatin dynamites rapidly decrease in sensitiveness to detonation and explosion by influence on aging while the ammonia dynamite was very little affected.

(3) That the insensitiveness of gelatin dynamites to detonation and explosion by influence on aging proceeds more rapidly the smaller the diameter of cartridge.

(4) That the insensitiveness to detonation and explosion by influence proceeds more rapidly with 60 per cent. strength L. F. gelatin dynamite than with 40 per cent. strength L. F. gelatin dynamite. Further information will be found in the report on this subject recently published by the bureau.

A New Amplifier of Sounds. L. GAUMONT. (*Comptes Rendus.*)—Many amplifiers of sound distort it without mercy. It is claimed that the following device is free from this defect. The vibrating part is a cone of fine silk fabric around which is wound a spiral of fine aluminum wire in one or more layers. The angle of the cone is 90°. This is introduced into the space between the pole pieces of an electromagnet which have the same angle. The cone fits over one of these. When telephonic currents are sent through the aluminum wire there are forces exerted upon the latter by reason of the interaction between its magnetic field and that of the electromagnet. Since the spiral has no natural period of its own, it does not reproduce the sound with distortion. Great distinctness is claimed as well as great intensity. G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 21, 1923.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 21, 1923.

MR. BENJAMIN FRANKLIN, *Temporary Chairman.*

The Board of Managers submitted its report. The report recorded the election to membership of:

T. Wistar Brown, 3rd, Esq., Attorney, 230 Chestnut Street, Philadelphia, Pennsylvania.

John Tracy Lay, Esq., B.S., Research Assistant in Physics, University of Pennsylvania, Philadelphia, Pennsylvania.

William C. Melcher, Jr., Esq., William Cramp and Sons Ship and Engine Building Company, Philadelphia, Pennsylvania.

Honorable William C. Sproul, Esq., B.S., President General, Refractories Company, 1512 Chestnut Street, Philadelphia, Pennsylvania;

lectures before the Sections as follows:

"Principles of Electrical Vibration Instruments" by
A. E. Kennelly, D.Sc.,
Professor of Electrical Engineering,
Harvard University and Massachusetts Institute of Technology
Cambridge, Massachusetts;

"Physics and Chemistry of Plant Life" by
Rodney H. True, Ph.D.,
Professor of Botany,
University of Pennsylvania,
Philadelphia, Pennsylvania;

"Motion Picture Photography for the Amateur" by
C. E. K. Mees, D.Sc.,
Director of Research Laboratory,
Eastman Kodak Company,
Rochester, New York;

"Tidal and Current Work of the Coast and Geodetic Survey" by
Lieutenant Commander G. T. Rude,
Chief, Division of Tides and Currents,
U. S. Coast and Geodetic Survey,
Washington, D. C.

and a lecture before the Stated Meeting, January 17, 1923, by
E. A. Eckhardt, Ph.D.,
Physicist,
Bureau of Standards,
Washington, D. C.
on "Building Acoustics";

also the following additions to the library, 47 bound volumes, 20 unbound volumes and 95 pamphlets.

The Board of Managers also transmitted the following memorandum and resolution:

"The Board of Trustees of The Franklin Institute have instructed the Fidelity Trust Company to sell a lot on Belfield Avenue in the City of Philadelphia, included in the bequest of William H. Wahl to the Institute. In order that the title to this lot may be properly passed, it is requested that the following resolution be adopted by the Institute:

"*Resolved,* That the title to premises known as Lot No. 28 on the Plan of Lots of the Walnut Lane Land Association situate on Belfield Avenue in the Twenty-second Ward of the City of Philadelphia, more particularly described in Deed dated March 10, 1892, recorded in Philadelphia in Deed Book T. G. No. 100, page 560 (except 20 ft. off the rear end previously sold), said Lot being a part of the devise to The Franklin Institute for the Promotion of the Mechanic Arts under the Will of William H. Wahl, deceased, and known as the 'John H. Wahl Fund,' be conveyed to the Trustees of The Franklin Institute in accordance with Article I, Section I, of the By-Laws of the Institute. And the President and Secretary are hereby authorized and directed to execute the Deed for the same."

Doctor Hoadley moved that the resolution, as presented, be adopted. The Motion was duly seconded and passed unanimously.

A report of progress was presented by the Committee on Science and the Arts.

The Chairman then announced that the next business of the meeting would be the presentation of the Elliott Cresson Medal to Dr. Lee deForest and recognized Mr. Charles E. Bonine, who said:

"*Mr. Chairman:* The invention of the three-electrode vacuum tube for the purpose of amplifying minute electrical currents and pressures, called by its inventor the Audion, and variously known as the electron amplifier, thermionic amplifier, three-electrode bulb, etc., which is the specific invention under consideration, is one of the most important ever made in the field of the electrical transmission of intelligence and through its development has worked a profound revolution in the art of radio communication.

"In consideration of this invention, marking as it does a signal advance in the art of electrical transmission of intelligence, The Franklin Institute awards the Elliott Cresson Medal to Dr. Lee deForest of Jersey City, New Jersey.

"Mr. Chairman, I take pleasure in presenting Dr. Lee deForest."

The Chairman presented the Medal, accompanying Certificate and Report to Doctor deForest who, in accepting the award, said:

"*Mr. Chairman, Members of The Franklin Institute, Ladies and Gentlemen:* It is useless for me to attempt to express in words my appreciation of the great honor conferred on me to-night by the Award of the Elliott Cresson Medal of the Institute.

"I can but regard this award, not as a personal one, to the inventor of the Audion, but rather as a tribute to the device itself, as an instrumentality

which has already proven itself as of very great and genuine value to mankind; and one which promises in the future to confer even greater benefits than those which it has heretofore given.

"Two years ago I presented before the Institute, a paper on the Audion. In this, I dwelt at some length upon the utility of the invention during the great War. To-night, I would speak, very briefly, upon the value of the Audion in Peace, in directly aiding in the cause of continued Peace.

"Although as early as 1907 I had foreseen the coming day when the Radio Telephone would be used in nation-wide, world-wide broadcasting, and although I had, in season and out of season, preached the benefits to our people which such broadcasting would bring, yet I did not foresee, two years ago, that the great wave of popularity and appreciation of this new medium was so nearly upon us.

"Nothing since the early days of the discoveries has so appealed to the imagination of a Nation. No other medium in man's history has demonstrated its unique power for uniting far-separated sections of a great country, for causing to become acquainted dwellers in distant districts—from north to south, from east to west. More than the newspaper, more than the postal service, this mighty service of hearing the spoken voice in greeting, the public address, the sermon, the lecture, the musical program—is actively uniting in a bond of common fellowship, common acquaintanceship, as no other conceivable instrumentality can accomplish.

"I predict that, as an educational medium, the Radio Telephone Broadcast will, in time, prove second in importance only to the Public School.

"As methods of transmission and reception become perfected, the benefits which we already see so clearly in the United States, will become international in scope. Already we see a closer interlinkage between the people of Canada and ourselves, due to the broadcasting idea. Soon these benefits will extend to Europe, and between the peoples of the old world, always heretofore strangers, enemies because strangers and personally unacquainted. When, night after night, the citizens of foreign lands will hear the friendly words, the music, the songs from across strange frontiers, then gradually will the feelings of enmity and suspicion, based chiefly on distances and ignorance of each other, change to understanding and good will.

"Thus, I maintain, the Radio Broadcast is destined to prove one of the most potent powers for the abolition of War in the history of the World.

"That the Audion as detector, amplifier, and transmitter has made possible this widespread introduction and popularity of Radio Broadcasting is, I consider, an adequate reason why it has been singled out to be honored by this Award, which you have seen fit to bestow here to-night."

After the transaction of the above business the meeting became a joint one with the Philadelphia Section of the American Society of Civil Engineers and the Chairman requested Professor William Easby, Jr., President, to preside.

The paper of the evening on "The Main Piers of the Bridge over the Delaware River between Philadelphia and Camden" was presented by Mr. Clement E. Chase, C.E., Principal Assistant Engineer, and Mr. M. B. Case, B.Sc., Senior Resident Engineer, Delaware River Bridge Joint Commission.

Mr. Chase described the construction of the granite and concrete piers upon which the great main towers of the bridge are to be supported. Details of the construction of the two largest pneumatic caissons ever used in a bridge foundation were given. The fundamental changes embodied in the design of these caissons based on experience with previous large caissons was pointed out. Recognition of the necessity for reducing the risks to the compressed air workers was reflected in provision of emergency refuge chamber, use of air locks, large enough to hold an entire shift and in the safety requirements of the specifications.

Mr. Case described the building of the complete pneumatic caissons ready for sinking, in one of the large shipyards, and contrasted the situation with other conditions frequently encountered in the building of bridges. The enormous area of the caissons made it desirable to keep the unit pressures at the cutting edge as small as possible during sinking to avoid excessive warping and racking stresses in the caisson structure. Procedure to accomplish this condition was described as was the ample equipment of hoisting shafts and air locks with convenient disposal of muck into barges alongside. Medical examinations and attention for compressed air workers was outlined with records of results accomplished. The plant and methods used for the construction of massive granite ashlar masonry was described.

Lantern slides were used to illustrate the subject.

The Chairman extended the thanks of the meeting to the speakers.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, February 7, 1923.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 7, 1923.

DR. JAMES BARNES *in the Chair.*

Mr. W. H. Fulweiler was unanimously elected Chairman for the year 1923.

The following reports were presented for final action:

No. 2763: Universal Measuring Machine. Final reading of report was held over until the March meeting.

No. 2785: Maxon Pre-mix Burner. The Certificate of Merit to Mr. Harry R. Maxon, of Muncie, Indiana.

No. 2798: Adjustable Hinge. Final reading of report was held over until the March meeting.

The following report was presented for first reading:

No. 2806: Literature.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A meeting of the Section was held on Thursday evening, January 11, 1923, at eight o'clock, with Mr. W. C. L. Eglin in the Chair.

A. E. Kennelly, D.Sc., Professor of Electrical Engineering, Harvard University and Massachusetts Institute of Technology, Cambridge, Massachusetts, presented the paper of the evening on "The Principles of Electrical Vibration Instruments."

These instruments are not only important from the practical standpoint, owing to their extensive every-day use, but their working theory bears remarkable analogies to alternating electric current theory. Some of these analogies are already known, but use is made of the motional-impedance circle for analyzing the behavior of these instruments comparatively. The principles of electrical vibration instruments, therefore, commend themselves to the notice of both mechanical engineers and electrical engineers.

The subject was fully illustrated by lantern slides.

After discussion of the subject by Dr. Carl Hering, Dr. W. R. Wright and others, a rising vote of thanks was extended to the speaker and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 25, 1923, at eight o'clock, with Dr. Joseph S. Hepburn in the Chair. The minutes of the previous meeting were approved as published.

Rodney H. True, Ph.D., Professor of Botany in the University of Pennsylvania, delivered an address on "The Physics and Chemistry of Plant Life." The relationship of osmotic pressure to plant nutrition and growth was described. The communication was discussed at length. On motion of Dr. Thomas D. Cope, a vote of thanks was extended to Doctor True.

The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Sections of Physics and Chemistry and Photography and Microscopy.—A meeting of the Sections was held in the Hall of the Institute on Thursday evening, February 1, 1923, at eight o'clock, with Dr. H. J. M. Creighton in the Chair. The minutes of the previous meeting were read and approved.

C. E. K. Mees, Sc.D., Director of the Research Laboratory of the Eastman Kodak Company, Rochester, New York, presented a communication on "Motion Picture Photography for the Amateur." A description was given of a process using special, narrow-width film, very small pictures, the direct production of positives by reversal during development, and special apparatus for taking and projecting. The lecture was illustrated by means of lantern slides and a demonstration of the process from taking the picture to projecting it on the screen.

The communication was discussed at length; a vote of thanks was extended to Doctor Mees; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 8, 1923, at eight o'clock, with Mr. Benjamin Franklin in the Chair.

The paper of the evening, entitled "Tidal and Current Work of the Coast and Geodetic Survey," was presented by Lieutenant Commander G. T. Rude, Chief, Division of Tides and Currents, U. S. Coast and Geodetic Survey, Washington, D. C.

The speaker gave an outline of the activities of the Coast and Geodetic Survey in tidal and current work, with special reference to recent investigations in the subject of wind-driven currents.

A non-mathematical explanation was given of the forces governing the making of the tides and currents and the different types of tides and currents were explained.

A brief description was given of the instruments and methods employed in the observation and prediction of tides and currents.

The paper, which was fully illustrated with lantern slides, dealt with the relation and importance of tides and currents to the work of the engineer, mariner and scientist.

After a short discussion a vote of thanks was extended to the speaker and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mining and Metallurgical Section.—A joint meeting of the Section and the Philadelphia Chapter, American Society for Steel Treating, was held in the Hall of the Institute on Thursday evening, February 15, 1923, at eight o'clock, with Mr. G. H. Clamer in the Chair.

Walter Rosenhain, D.Sc., F.R.S., Superintendent, Metallurgy Department, The National Physical Laboratory, Teddington, England, presented a paper on "The Structure and Constitution of Alloys." The speaker emphasized the increasing importance of full detailed knowledge of the internal structure and constitution of alloys and reviewed the methods of studying structure and constitution which have been recently developed and some of the more important results obtained. The methods discussed included those relating to the thermal study of alloys by means of heating and cooling curves and their interpretation. He indicated, however, the importance of microscopic examination of alloys in various states obtained by special methods of preparation, including prolonged annealing at carefully controlled temperatures, very gradual cooling and quenching from accurately known temperatures. The application of these methods to the fundamentally important problem of determining the solubility of metals in one another in the solid state and to the study of ternary and other complex alloys, was described with special reference to alloys of aluminum whose structure, constitution and properties have recently been investigated in the lecturer's laboratory.

The subject was illustrated by lantern slides.

After an interesting discussion by the Chairman and others, a vote of thanks was extended to the speaker.

Adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 14, 1923.)

LIFE MEMBERSHIP.

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NECROLOGY.

Mr. Clarence S. Bement, 3907 Spruce Street, Philadelphia, Pennsylvania.

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BOOK NOTICES.

CAROTINOIDS AND RELATED PIGMENTS: THE CHROMOLIPOIDS. American Chemical Society, Monograph Series. By Leroy S. Palmer, Ph.D., Professor of Agricultural Bio-chemistry, University of Minnesota. 316 pages including indexes and bibliography, illustrations and plates, 8vo. New York, The Chemical Catalog Company. Price $4.50 net.

With the formal statement that this book has the general merits of good printing, paper and illustrating that have characterized all the volumes so far issued in this A.C.S. series, the reviewer can pass to the interesting but somewhat difficult task of presenting the essential features thereof. A

difficult task, not because the subject is imperfectly handled, but because it takes the reader into a highly specialized field of bio-chemistry, a field which lies at present well outside the general scope of organic chemistry as presented in our standard text-books and taught in our colleges and schools.

Color is widely distributed in nature, and is by no means limited to living organisms. Many natural minerals are characteristically colored, and the chemist encounters a vast array of brilliantly colored products in inorganic work. "Color-tests" are now-a-days among the most common methods of analysis, and the enormous number of synthetic dyes that have been obtained from tar has had a profound influence on the course of events in the half century that has elapsed since the so-called "anilin colors" were commercially produced. Color, indeed, is the basis of beauty in nature. We may be impressed by the clouds and the seascape, but our reaction to a brilliantly colored scene is much more emotional. The old experiments of illuminating a variety of colored objects with monochromatic light, especially sodium light, will show us how tame would be the world around us if the production and perception of color did not exist.

Doctor Palmer points out that color arises from two distinct conditions, structure and actual power of absorbing certain rays of light. Structural origin is seen abundantly in the phenomena developed by reflection of light from colloidal particles or from the films, as in the soap-bubble. True pigments are substances that absorb certain colors when illuminated with white light and reflect the others. The reflected light determines the color of the active surface. In many cases, however, the separation is incomplete; much white light may be mixed with the reflected rays, and thus a misleading effect be produced. Gold, for instance, is red, but in a single reflection appears yellow; by repeated reflections the true color is obtained. In a considerable number of cases the separation results in one combination of waves passing through while the remaining waves are turned back. Such substances termed, "dichroic," give one color when looked at, and the complementary one when looked through. Many of the synthetic coal-tar colors show this property.

The book in hand is devoted to yellow, orange-yellow, orange-red and red pigments occurring in living organisms. The term "carotinoid" is derived from "carotin," the first yellow pigment isolated in crystalline form, occurring in the carrot, *Daucus carota* L. The name was used to include all plant chromolipoids, but investigation showed that differences exist between these, and the name was changed to carotins, many workers also using the term "carotin group." Carotin was found to be a hydrocarbon and the name "carotene" was proposed. Doctor Palmer states that the London Chemical Society favors the spelling "carrotene." What is the reason for this is not stated, and the name "London Chemical Society" is not quite apt, as the British organization has always been known as "The Chemical Society" without indication of country or special location.

In the progress of research, it was ascertained that some of these pigments are hydrocarbons and others contain oxygen. The former were distinguished by Zopf as "eucarotins," the others are "carotinins." These latter are capable of uniting with certain metallic elements. Another group of pigments is the

"xanthophylls." These, like the carotinoids, exist both in plants and animals and are related thereto.

The book leads into a field practically unknown to chemists engaged in teaching or in commercial work. Extensive as have been the researches and the bibliography thereof, many of the most frequently recurring names of investigators are unfamiliar in the general literature of the science. Yet the highly specialized nature of this line and the comparative lack of results directly bearing on the applied phase of the science, must not lead to any deprecation of the labor. The object of science is the discovery of truth; the benefit to be derived from knowledge is not the primary urge. In the book before us, indeed, a very interesting practical result is described. During the war, a strategic use was made of fake foliage. Canvass or other suitable material was painted to represent plants. It was found that real foliage reflects differently from ordinary green paint, and light filters were developed in the Eastman Laboratories by which the aviator was enabled to distinguish the true from the false, the latter appearing green and former red through these filters. Professor Wood in his researches in invisible light found that ordinary foliage photographed by infra-red light appears as if covered with snow.

From his viewpoint as a bio-chemist, Doctor Palmer is led to express opinions on the value of the carotinoids and allied substances in the life struggle of plants and animals. He is not at all favorable to the theories of mimicry and protective resemblance that have found such wide acceptance among naturalists since the days of Darwin and Wallace, and pays his respects to such views in anything but courteous phrase. Referring (p. 158) to a suggestion that a color in the eggs of an insect has been regarded as a protection, he says

> "Although the writer is not in sympathy with the protective notions regarding animal colorations, believing that such phenomena are to be explained entirely on physiologic grounds, and not through theories built upon the assumption that colors impart the same sensations upon the retina of the eyes of lower animals that they do upon our own, it is nevertheless an interesting fact that insects apparently have the ability to impart derived pigments found in the blood to their eggs just as is found in the case of the higher oviparous animals."

Exception must be taken to the form, spirit and science of this sentence. The word "protective" should qualify "animal colorations," the theories deserve a kindlier allusion than to be called "notions," and the statement that the colors may be explained on physiologic grounds is a mere truism. All the phenomena in living organisms can be explained on physiologic grounds, using the term "physiology" to include the processes of physics, physical chemistry and chemistry, but the data at hand are too few to furnish such explanations. Doctor Palmer's criticism almost seems to involve the assumption that naturalists believe that the insect colors its eggs by intention, but the doctrine of natural selection is that a given living organism, having acquired by physiologic processes, without its conscious action or any outside consciousness some property or method which inures to its advantage in the struggle for

existence, this property or method will be likely to be perpetuated by inheritance and to be continuously advanced in relative function.

The allusion to the possibility that the lower animals do not have the same perceptions of color as human beings is little more than a red herring drawn across the trail. It is not a question whether an insect or a bird perceives a red mass upon a green leaf the same as we see them, but whether there is such a contrast as enables the animal to distinguish one object from the other.

High praise must be given to the author of the work for the patience and care with which the literature of this difficult subject has been searched and abstracted. The bibliography shows that his own labors have been extensive and fruitful. He has had in view not only a comprehensive presentation of the existing knowledge, but to indicate to beginners lines of investigation worthy of pursuit. In view, however, of the many lines of investigation now open, in which striking theoretical and practical results are likely to be obtained, it is doubtful whether the somewhat abstruse and certainly difficult field of the carotinoids and allies will be attractive to many. Doctor Palmer gives a scheme for the pronunciation of several of the most important terms used in the book. Exception may be taken to the accenting of "chromatogram" on the last syllable. That seems to make the pronunciation difficult and it is likely that most speakers will accent the antepenultimate. The tendency in English seems to be to move the accent towards the beginning of the word. "Par-e'-sis" has become "par'-e-sis," and "tel-e-graph'-y," "teleg'-raphy." Following the custom of most of the books issued by the publishing firm, some attempt is made at simplified spelling, but it is in a weak and practically useless form. The only noticeable change is in spelling sulphur and its derivatives with an "f," a change which involves no phonetic gain. It is a puzzle why xanthophyll and chlorophyll are not likewise spelled with "f" and further why a double "l" is used in these and similar terms. A far more useful modification would be to get rid of the final "e" in the names of binary compounds. A few typographic errors have been noted. These are all of the type practically unavoidable, and mostly not misleading. On page 42 in the last paragraph, "benzine" should be "benzene," on page 155 "*Insectia*" should be "*Insecta*" and on the same page and in the bibliography, page 287 "Medola" should be "Meldola."

An interesting question is whether there is any relation between carotin and vitamin A. This is discussed at considerable length. It has been declared by one investigator that the two are identical, but the data at hand negative that view. The decision is that although vitamin A like carotin and its allies is taken in by animals through food and not elaborated in the organism, the two are wholly distinct. In the course of the chapter, Doctor Palmer makes another criticism of the theories of mimicry and protective resemblance, telling us that he "does not possess a biologic viewpoint which is sufficiently developed along academic lines to appreciate 'function' as an abstract attribute of living organisms." *Tantæne animis cœlestibus iræ?*

The reviewer's disagreement with some of the author's inferences as to the functions of plant and animal colors in interrelations in nature, that is,

in the struggle for existence, must not be allowed to obscure the commendation which the book deserves as a summary of the vast and intricate data already accumulated in this field, nor to belittle the author's own extensive contributions and his eminent fitness for the task he undertook. In passing from the pure science of the subject to accessory topics, he enters the stormy area of discussion of "design and purpose" in nature, in which difference of opinion is sure to arise and to be expressed with feeling. After all, perhaps, the world of science is benefited, as is the world of diplomacy, by an occasional dispute, and King Gama may be right when he sings:

"Oh, don't the days seem lank and long
When all goes right and nothing goes wrong;
And isn't life extremely flat
With nothing at all to grumble at?"

HENRY LEFFMANN.

THE MICROSCOPY OF SMALL ARMS PRIMERS. By Emile Monnin Chamot. Heckscher Foundation for the Advancement of Research, Cornell University, Ithaca, New York, 1922. 61 pages, 21 plates, 2 figures in text, 23 x 30 cm.

A primer, or more precisely a percussion primer, is the tiny device, containing the priming composition and an anvil, which is placed in the bottom of a small-arms cartridge case for the purpose of initiating the ignition and consequent explosion of the powder charge enclosed in the case or shell. Percussion primers are the direct successors and most recent development of the percussion cap used on the nipples of the older forms of pistols and muskets. Like the percussion caps percussion primers each contain a minute quantity of a composition designed to promptly ignite and emit a spit of flame when struck a blow by the firing pin of the gun upon the anvil. Though the charge of the primer composition in the cup of a percussion primer may be but one-half of a grain or less in weight, yet unless the primer functions normally with certainty under all conditions of service use the whole system fails, rendering the firearm useless, and this effect is particularly disastrous in magazine rifles and machine guns, where the loading, firing and ejecting mechanism is operated by the explosion's gases, for a single defective primer in the whole train may interrupt the firing at a critical moment, put the gun out of action and turn the tide of battle. Moreover, certainty of action of primers became the more imperative when machine guns were so coördinated with the propellers of aircraft as to fire between the blades of the latter, since a hang-fire might result in the carrying-away of the blades of the propeller and the wrecking of the plane.

It was not surprising therefore that a feeling of the gravest apprehension spread through the nation when, shortly after the entrance of the United States into participation in the Great War, it was reported that the ammunition for the supply of our troops contained defective primers. Under House Resolution No. 134 of the Congress an investigation was carried out. The record of the testimony and opinions given at the "hearings" of the committee, published as a pamphlet of 178 pages, shows the reports to have been true and that misfires and hang-fires due to this cause were not infrequent. At once the War

Department sought experts in a variety of fields to bring their special knowledge and capacities to the remedying of these most serious defects. Among those thus called upon was Doctor Chamot, Professor of Chemical Microscopy in Cornell University and author of an authoritative manual in this field of science, who brought his special facilities, methods and technic to the solution of the problems of producing permanently reliable primers and of developing practical methods of inspection which would disclose defective primers and expose the nature of their defects so that they might be avoided in further manufacture. He found the subject of study so interesting that "After all work for the Ordnance Department ceased, the author continued the studies upon the material still in hand and upon such other primers and ammunition as he was fortunate enough to obtain. Not being now pressed for time, it was possible to check up doubtful facts and improve methods and apparatus. This monograph is based, therefore, almost entirely upon after-war data, and the illustrations, with three or four exceptions, are from photographs taken during this last period."

The topics covered in this monograph are the history and descriptions of early percussion caps and pin-fire cartridges; typical modern military rifle cartridges; the causes of primer malfunctions; manufacture of primers; microscopes for the investigation of primers; comparison microscopes; melting points determined microscopically; tools and appliances for microscopic primer studies; methods for removing primers from cartridges; microscopic examination of primer pellets; removing anvils from primers; wet primer pellets; texture of pellets; sectioning primers; microscopic appearance of pellets; microscopy of primer cups; protective coatings; microscopy of pellet components; firearm malfunctions; and the relative proportion of different types of malfunctions.

With the aid of an abundance of photographs and photomicrographs, Doctor Chamot describes in great detail the various instruments and tools (many of them devised for this research) employed in his investigations, as well as the technic he has developed so that hereafter primer manufacture may be properly supervised and consignments properly inspected. It has been generally believed that because primers are very sensitive to percussion they are equally sensitive to other mechanical effects. It was therefore a matter of much surprise to find they could be sectioned vertically so as to disclose the most important facts, their general morphology and internal structure relative to mis-fires, and very large numbers were thus sectioned in the author's laboratories with no disastrous results. In fact, following his technic and adopting his safeguards "*one may saw through the pellets of most primers with a fine-toothed saw almost as nonchalantly as through a piece of wood or metal.*" The many photomicrographs of sectioned percussion caps and primers shown are the most novel and interesting of the many illustrations presented in this brochure and they disclose to the least discerning a great variety of defects to which primers may be subject unless means are provided in advance for their prevention.

From an analysis of some hundred of cartridge mis-fires Doctor Chamot finds 28.5 per cent. due to defects in assembly and other mechanical imperfections, 25 per cent. to poorly compressed or thick pellets, 12.6 per cent. to too low a temperature of the "spit" of the primer, 7.7 per cent. to segregation

of the primer components and 12.59 per cent. to causes not enumerated. Other causes enumerated were incipient explosions, 4 per cent.; pellets too thin under the anvil, 4 per cent.; pellets which were probably cracked or were fired in the primer seating presses, 3.4 per cent.; pellets contaminated with oil, 2.2 per cent., and foreign matter under the anvils, 0.01 per cent., but seldom was primer malfunction due to a single imperfection only. One is impressed by this rehearsal of actual defects found with the extreme care that must be exercised in the manufacture of this tiny but fundamental and prime device. There seems to be something uncanny in the behavior of matter as when a larger particle of a comminuted component of the composition finds its way past the sieve it deliberately, apparently, seats itself over the anvil so as to receive the impact of the firing pin and, being by itself inert, prevents the initiation of the explosion, and yet this is well shown in Fig. 2 on p. 55, where an egg-shaped particle of potassium chlorate lodged in the manner described.

Little attention is given to the many specific formulæ for primer compositions, but the chemical and physical characteristics of the components of these mixtures are described in detail and the appearances of many of them as they are viewed under the microscope are shown in splendid photomicrographs so that the chemical and physical means for the identification of each of these components present in minute quantities in the field of the microscope is made very clear, but no reference is made to the potassium bromate that engaged attention at the hearings before Congress. Not the least ingenious of the methods presented is that for the determination of the melting points of small particles of these components, an instrument for this purpose having been devised for this investigation by providing an ordinary petrographic microscope with an electrically heated stage and a drawing camera so arranged that the observer can view the object being heated and the scale of the voltmeter at the same time.

This record adds many to the rapidly increasing list of examples from precise chemical investigations showing definitely the large effects of "little things" and the absolute necessity of taking full account of little things to secure a definite and uniformly reliable product. For instance, many "malfunctions" were examined in which distorted cups, due to unequal thickness, were the only defect which could be discovered. The shape and emplacement of an anvil and the curve of the primer pocket are contributing causes to success or failure. Even a feather edge on a cup may cause mis-fire. In testing by the "drop test" with a 4-ounce steel ball, the ball had to fall from 2 to 4 inches greater height to explode a primer having a feather-edged cup and a deep-seated anvil than was required to explode a normal primer. The tiny discs with which the pellets in the cups are covered to protect them from moisture, and which are therefore interposed between the pellet and the anvil, received attention. Frequently these discs are punched from very tough, long fibred, Manila paper, and sometimes this paper is coated with shellac. In some instances discs of foil made from tin-lead alloy are employed. Doctor Chamot found this paper to possess a low inflammability and to offer remarkable resistance to the explosion. "It therefore interposes a real barrier between the flash of the primer and the powder charge. It is

ruptured only with the greatest difficulty" and this is shown in one of the photomicrographs exhibited. Moreover "hard, stiff paper discs, such as result from too heavy shellacing, are apt to pucker and fold under the pressure of a decidedly conical anvil, and finally assume a funnel shape with a sharp point. This point is sufficiently hard and rigid to penetrate deeply into a fresh, soft pellet. One lot of primers prepared just as we entered the war was found to have most of the pellets so deeply indented by the paper that very little detonating mixture remained between anvil and cup. The point of the paper cone also probably deadened the blow of the striker and thus contributed in part to producing primers of poor quality and abnormally low sensitivity." He holds that "Whatever objections there may be to the use of thin metal foil (tin-lead alloy) it is certain that it properly protects the pellet, clings tightly to pellet and sides of the cup, and adequately water-proofs the primer, and is easily ruptured and completely destroyed by the explosion of the detonating mixture. Considerable care must, however, be taken in seating the discs."

Although the existence of the defects in primers rehearsed above, and others, were demonstrated, yet in reality a very large number of mis-fires which are blamed on primers are really due to arm or cartridge malfunctions. Moreover, "the non-standardization of firearms forces upon the manufacturers of primers a problem of the first magnitude. Primers are required which will properly function in all guns of the same calibre, irrespective of the spring tension of hammer or bolt, and irrespective of the size and the shape of the end of the firing pin." "It appears to be expected by ordnance men that a primer can be produced which will function equally as well in a gun delivering a firing-pin blow equivalent to a spring tension of about five pounds as in a gun delivering a twenty-five pound spring tension blow." To show that this charge of variations in blows and in the conformation of firing-pin points are facts photomicrographs of the heads of 35 primers of the same class, most of which had malfunctioned in machine guns or rifles, are presented, all the different .30 calibre machine-guns used in the American army being represented, and it is said "One who is familiar with the characteristics of the different guns will probably have little difficulty in assigning firing-pin marks each to its own proper gun. Besides a group—or type-characteristic—each individual arm usually imprints upon a primer a pattern peculiar to its own firing-pin. The microscope will almost unfailingly reveal whether a given number of primers have been fired in one or several different guns and will enable the investigator to decide which gun, if the guns are available for study." Doctor Chamot may not be aware that this last-mentioned method was resorted to, without success, in the endeavor to find the criminals in the notorious Brownsville riot.

This monograph is presented on heavy calendered paper throughout, which brings out the halftones in a vivid manner, and with clear-faced type. The Heckscher Foundation is to be congratulated in that one of its earliest publications should be so authoritative a document and presented in so attractive a form.

CHARLES E. MUNROE.

THE THEORY OF EMULSIONS AND EMULSIFICATION. By William Clayton, D.Sc., F.I.C. 160 pages, 22 illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1923. Price, $3 net.

Technical terms are so extremely numerous in science that most persons shrink from searching into the primitive meaning even of those that have not been specifically coined. Yet there are curious instances of perversion of meaning by the course of events and by the laws of word evolution. Alcohol, for example, originally meant a fine powder, and in the early part of the nineteenth century, Davy spoke of the "alcohol of sulphur," meaning the finely divided precipitated form. So the word "emulsion" comes primarily from the Latin "emulgere," which means to drain out all liquid, especially to drain out milk. In one of its earliest uses it is spelled "emulction." The term has long been applied to the intimate mixtures of two liquids not appreciably soluble in each other, and its use in this respect is derived from the physical nature of milk which is practically an emulsion of fat in a complex water solution. Considerable difference, however, exists between milk and the common emulsions. The liquid portion of normal milk probably contains proteins in a colloidal condition, in which the milk globules float. The latter are due to the fatty degeneration of the epithelial cells lining the tubules of the milk gland, so that in a certain sense the secretion is a process of disease. Milk globules do not spontaneously coalesce, which property may be due either to a distinct membrane or to a hardened external layer. The most familiar forms of emulsions are those of oil, either fatty or hydrocarbon, in water. Some of them have been long known and the methods of obtaining them invented in a remote past. The scientific study of the conditions dates from a recent period and is one of the phases of rapid development of colloid chemistry.

Doctor Clayton has collected in this book a very large amount of data bearing upon this subject which has both practical and theoretical interest. An emulsion is scientifically defined as a system containing two liquid phases one of which is dispersed as globules in the other. The earliest types of emulsions were those of oily, that is, water-repellent liquids dispersed in water. Temporary emulsions of this type can be easily obtained by shaking the oil and water together, but the globules soon begin to coalesce and two strata are formed. Water-in-oil is a more recent type. When the proportion of oil to water is very small, a stable emulsion may be obtained by mechanical means, such an effect being often observed in engine-condenser water, the proportion of oil being about 1 in 10,000. Here the physical condition approaches that known as colloidal. For preparing stable emulsions with appreciable proportions of both ingredients, a third substance is usually required. Obviously, the nature of the emulsifying agent materially affects the emulsion produced. Water-soluble colloids promote the formation of oil-in-water forms and oil-soluble colloids promote the reverse conditions. Pharmaceutic emulsions have long been extensively used, principally the oil-in-water form and a number of substances have been employed as determinants. Alkalies act merely by forming soaps with the free fatty acids present in the oils, soaps being excellent emulsifiers.

In addition to presenting the physics and chemistry of emulsification and the discussion of the theories now or formerly held concerning the phenomena,

an interesting chapter is added on de-emulsification. This has become of great industrial importance on account of the occurrence of natural emulsions of valuable liquids, and the frequent production of tenacious forms in some manufacturing operations. Oil wells not infrequently yield a product containing considerable closely intermixed water. The majority of this settles out on standing, but a small proportion remains. As crude oil, to be saleable, must not contain more than 2 per cent. of water many processes have been devised to get rid of the excess. It is believed that the emulsifying agent in these cases is asphalt. Doctor Clayton divides the procedures for removing water into three classes: Electrical, chemical, and mechanical. The electrical method depends principally upon the tendency of the water globules to follow the passage of an electric current. Cottrell, whose methods of dealing with dusts are well known, was the pioneer in patents for such de-emulsification. A plate is given of very large dehydrating plant in California dealing with a very troublesome emulsion of 40 per cent. of water. In connection with the discussion of the electrical methods, a striking illustration of the progress of the action is given by means of the reproduction of a motion picture taken by magnification and showing the gradual coalescing of the oil globules. A mixture consisting principally of sodium oleate is marketed for this purpose. Many other chemical methods are mentioned. Centrifugal separation has long been employed in the removal of butter-fat from milk. The DeLaval separator, though not the first machine devised for the purpose was the first one operating continuously, and is widely known. The principle of the centrifuge has been applied in many ways, and very high-speed forms have been recently introduced.

High commendation must be given to the author of this work, not only for the thoroughness with which the field has been garnered, but to the excellent form in which the material has been presented. One most commendable feature is the manner in which references are given. These are very numerous. Journal articles are quoted both by year and volume and the latter is printed in heavy-faced Arabic numerals thus avoiding the complex Roman numbers. In quoting books the year of publication is given. The mechanical execution of the book is also highly commendable and the work may well serve as a model for monographs of its kind.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 136, Damping Coefficients Due to Tail Surfaces in Aircraft, by Lynn Chu, Massachusetts Institute of Technology, Condensed and Modified by Edward P. Warner. 14 pages, illustrations, quarto. Washington, Government Printing Office, 1922.

The object of the investigation described in this report was to compare the damping coefficient of an airfoil as calculated from a knowledge of the static characteristics of the section with those obtained experimentally with an oscillation. The damping coefficients so obtained, according to the conventional notation, can be considered either as due to pitching or as due to yawing, the oscillation in these experiments being so arranged that the surfaces oscillate about a vertical axis. This is in reality the case when the influence

is yawing about the standard Z-axis, but it can also be considered as a pitching motion when the model is so rigged that its standard Y-axis becomes vertical. This horizontal oscillation has the advantage of eliminating the gravity action and avoiding the use of counterweights, whose presence in the wind-tunnel is undesirable because of their interference with the air flow. The real point of the investigation was to separate the damping due to rotation from that due to translation. By varying the distance between the centre of pressure and the centre of rotation on the oscillator, the variation of damping moment can be observed and the rotational and translational effects can be separated.

Report No. 143, Analysis of Stresses in German Airplanes, by Wilhelm Hoff, Director of the Deutsche Versuchsanstalt für Luftfahrt. 52 pages, illustrations, plates, diagrams, quarto. Washington, Government Printing Office, 1922.

This report contains an account of the origin of the views and fundamental principles underlying the construction of German airplanes during the war. The report contains a detailed discussion of the aerodynamic principles and their use in determining the strength of airplanes, the analysis of the strength qualities of materials and in the construction, the calculated strength of air flows and a description of tests made in determining the strength of airplanes.

Report No. 145, Internal Stresses in Laminated Construction, by A. L. Heim, A. C. Knauss and Louis Seutter. Forest Products Laboratory. 56 pages, illustrations, quarto. Washington, Government Printing Office, 1922. Price 10 cents.

This report reviews the procedure employed in an investigation of the sources and influence of internal stresses in laminated construction, and discusses the influence of shrinkage and swelling stresses caused by atmospheric conditions upon the tensile strength across grain in laminated construction with special reference to airplane propellers.

The investigation covered three sources of internal stress, namely, the combination of plain-sawed and quarter-sawed material in the same construction, the gluing together of laminations of different moisture contents, and the gluing together of laminations of different densities.

Glued specimens and free specimens, made up under various manufacturing conditions, were subjected to various climatic changes inducing internal stresses and then were tested. The strength of free unstressed pieces served as a standard of comparison for glued pieces and indicated what internal stresses were developed in the glued construction.

Report No. 151, General Biplane Theory, by Max M. Munk. 47 pages, illustrations, quarto. Washington, Government Printing Office, 1922.

Report No. 151 deals with the air forces on a biplane cellule. The first part of the report deals with a two-dimensional problem neglecting viscosity. For the first time a method is employed which takes the properties of the wing section into consideration. The variation of the section, chord, gap, stagger, and decalage are investigated, a great number of examples are calculated, and all numerical results are given in tables. For the biplane without stagger is found that the loss of lift in consequence of the mutual influence of the two wing sections is only half as much if the lift is produced by the curva-

ture of the section as it is when the lift is produced by the inclination of the chord to the direction of motion.

The second part deals with the influence of the lateral dimensions. This has been treated in former papers of the author, but the investigation of the staggered biplane is new. It is found that the loss of lift due to induction is almost unchanged, whether the biplane is staggered or not.

The third part is intended for practical use and can be read without knowledge of the first and second parts. The conclusions from the previous investigations are drawn, viscosity and experimental experience are brought in, and the method is simplified for practical application. Simple formulas give the drag, lift, and moment. In order to make the use of the simple formulas still more convenient, tables for the dynamical pressure, induced drag, and angle of attack are added so that practically no computation is needed for the application of the results.

Report No. 152, The Aerodynamic Properties of Thick Aerofoils, by F. H. Norton and D. L. Bacon. Langley Memorial Aeronautical Laboratory. 15 pages, diagrams, quarto. Washington, Government Printing Office, 1922. Price 5 cents.

This investigation was undertaken for the purpose of studying the effect of various modifications in a given wing section, including changes in thickness, height of lower camber, taper in thickness, and taper in plan form with special reference to the development of thick, efficient airfoils. The method consisted in testing the wings in the N.A.C.A. 5-foot wind-tunnel at speeds up to 50 metres (164 feet) per second while they were being supported on a new type of wire balance. Some of the airfoils developed showed results of great promise. For example, one wing (No. 81) with a thickness in the centre of 4.5 times that of the U.S.A. 16 showed both a uniformly higher efficiency and a higher maximum lift than this excellent section. These thick sections will be especially useful on airplanes with cantilever construction.

Report No. 153, Controllability and Manœuvrability of Airplanes, by F. H. Norton and W. G. Brown. Langley Memorial Aeronautical Laboratory. 18 pages, illustrations, quarto. Washington, Government Printing Office, 1922. Price 5 cents.

In this report are given the results of investigations carried out for the purpose of studying the behavior of the JN4h airplane in free flight under the action of its controls and from this to arrive at satisfactory definitions and coefficients for controllability and manœuvrability. The method consisted in recording the angular velocity about the three axes, together with the airspeed, control positions, and acceleration. An analysis of the records leads to the following results:

1. Both the maximum angular velocity and maximum angular acceleration are proportional to the displacement of the controls.

2. Both the maximum angular velocity and maximum angular acceleration for a given control movement increase with the airspeed, rapidly immediately above the stalling speed, then nearly proportional to the speed.

3. The time required to reach each maximum angular velocity is constant for all airspeeds and control displacements for a given airplane.

4. The minimum time required to reverse the direction of an airplane by a steeply banked turn is a rough indication of its general manœuvrability.

5. Doubling the lateral moment of inertia of an airplane increases the time required to bank at 90°, with a maximum control angle, by only 10 per cent.

6. Controllability has been defined as applying to the moment produced about the centre of gravity by the action of the controls and manœuvrability as the resultant motion.

7. A simple method is described for measuring the controllability coefficients $\frac{dL}{di_x}$, $\frac{dM}{di_y}$, and $\frac{dN}{di_z}$, and the manœuvrability coefficients t_ϕ, t_ϵ, t_ψ, and $\frac{(V\min)^2}{g}$.

These results are of practical value, as they give a quanitative means of measuring airplane manœuvrability and controllability, which will allow designers to accurately compare the merits of different airplanes.

Report No. 155, A Study of Airplane Manœuvres with Special Reference to Angular Velocities, by H. J. E. Reid. Langley Memorial Aeronautical Laboratory. 9 pages, illustrations, quarto. Washington, Government Printing Office, 1922. Price 5 cents.

With a view to increasing our knowledge on the behavior of the airplane during various manœuvres and to obtain values of the maximum angular velocities and accelerations in flight, this investigation was undertaken.

The method consisted in flying a JN4h airplane through various manœuvres while records were being taken of the control position, the airspeed, the angular velocity and the acceleration along the Z-axis. The results showed that the maximum angular velocity about the X-axis occurred in a spin and amounted to 2.43 radians per second, while about the Y-axis the maximum was 0.96 radian per second in a barrel roll. The maximum angular acceleration about the X-axis of −2.10 radians per (second)^2 occurred in a spin, while the maximum about the Y-axis was 1.40 radians per (second)^2 when pulling out of a dive. These results have direct application to the design of airplane parts, such as propeller shaft and instruments.

Report No. 156, The Altitude Effect on Air Speed Indicators—II, by H. N. Eaton and W. A. McNair. 46 pages, illustrations, quarto. Washington, Government Printing Office, 1922.

The report opens with a discussion of the theory of the performance of airspeed nozzles and of the calibration of the indicators, from which the theory of the altitude correction is developed. Then follows the determination of the performance characteristics of the nozzles and the calibration constants used for the indicators. In the latter half of the report the viscosity correction is computed for the Zahm Pitot-Venturi nozzles, army and navy types, which are the most commonly used airspeed nozzles in the United States. It will be found that the viscosity correction is far from negligible, since under certain conditions it may amount to 20 per cent. or more of the indicated airspeed. Tables and plots are given to enable the readings of Pitot type and Zahm Pitot-Venturi type indicators to be corrected for any atmospheric conditions which may be experienced by either heavier-than-air or lighter-than-air craft and for airspeeds up to approximately 200 miles per hour. Evidence is also adduced tending to show that the effect of the compressibility of the

atmosphere on the performance of Venturi airspeed nozzles is not numerically greater than the corresponding effect on Pitot tubes, and can be neglected over the range of flying speeds commonly attained to-day.

UNITED STATES COAST AND GEODETIC SURVEY, TERRESTRIAL MAGNETISM. Magnetic Declination in the United States for January 1, 1920, by Daniel L. Hazard, Assistant Chief, Division of Terrestrial Magnetism. 30 pages, map, 8vo. Washington, Government Printing Office, 1922. Price, five cents.

This publication is intended primarily to supply information regarding the earth's magnetism needed by navigators and land surveyors, but the data which it contains are of much value also to map makers and geophysicists.

The magnetic work of the United States Coast and Geodetic Survey, begun as one of the essential parts of the preparation of nautical charts of the coastal waters, has been extended to cover the interior of the country to meet the needs of the surveyor. Nearly all of the early land surveys in the United States were made by compass and the boundaries in the deeds were defined by compass bearings, and in many localities and for certain kinds of surveying (especially the retracing of the lines of old compass surveys) the compass is still in use. The compass does not, in general, point true north nor is its direction at any place constant, hence knowledge of the compass variation (magnetic declination) and its changes is required by those who make use of the compass. The object of this publication is to supply that information for the United States. The distribution of the magnetic declination and its annual rate of change for the beginning of 1920 are shown graphically on an isogonic chart. The secular change of the declination since 1750, or the date of the earliest observations, is given in tabular form for one or more places in each State. Tables are given also to show the manner in which the declination changes in the course of the day, the so-called diurnal variation.

Methods of determining the true meridian are explained, so that the surveyor may determine the magnetic declination for himself at places where there is no meridian line or other true bearings available.

OUTLINES OF THEORETICAL CHEMISTRY. By Frederick H. Getman, Ph.D. Third edition, thoroughly revised and enlarged, xi-625 pages, 149 illustrations, 8vo. New York, John Wiley and Sons, Incorporated, 1922. Price $3.75.

The "small thin volume" of the first edition of Remsen's "Theoretical Chemistry" was at one time the American student's principal guide to the fundamentals of the science. In the earlier treatises on this subject, mathematics had but little concern. Chemical formulæ have to the uninitiated the appearance of algebra, but have no appreciable relation to it. A wise change was made when chemists began to write the exponents as inferiors, a change which, unfortunately, our French co-workers have not yet adopted. Most of them, however, have got over using Az for N.

The development of physical chemistry, and the invasion of physical concepts and physical methods into chemical procedures have greatly changed

the aspects of our works on the theories of the science. Data of all kinds have accumulated and great shifting has taken place in the views as to many forms of chemical reactions. The first editon of Remsen issued 1877 was a 12mo of 228 pages. A hasty inspection of its pages does not show one algebraic formula. The book before us, an octavo of over six hundred pages, bristles with complex expressions involving higher mathematics. Being a third edition, it is not necessary for the reviewer to discuss in any detail its merits. The first edition was published in 1913. The table of contents shows that the subject is fully covered. The last chapter gives twenty-four pages to a lucid and comprehensive exposition of the latest views on atomic structure, in the course of which isotopy is noted, and this subject is also included in the section on the electrical theory of matter. In this connection attention may be called to an unhappy development in nomenclature. Dr. A. W. Stewart in 1918, in an article in the *Philosophical Magazine*, suggested the word "isobare," in application to elements having the same atomic weight, but differing in properties, a sort of converse of "isotope." He remarks that the word "isobar" would be preferable but this has already been appropriated in meteorology as the term for the lines of equal barometric pressure, in comparison with "isotherm." To prevent this overlapping, Stewart changed the spelling slightly. It is to be regretted that he did not at the same time either indicate the pronunciation or adopt such a spelling as will leave no serious doubt in that line. It is now uncertain whether the last syllable rimes with "far" or with "fare." Analogy is no definite guide in English, but it is to be hoped that the value of the final, but silent, "e" will be preserved, and that the term will rime with "fare," awkward as that is considering the etymology. Such pronunciation will, however, have the advantage of following the analogy of "isotope."

As regards the book itself, it is an excellent guide to the subject, well printed on good paper.

HENRY LEFFMANN.

DIE TECHNIC DER ELEKTRISCHEN MESSGERÄTE. By George Keinath, Eng. D. Second enlarged edition, vii–477 pages, 400 illustrations in the text. Munich and Berlin, R. Oldenbourg, 1922. Price, paper, $4.80; bound, $5.

A comprehensive review of the first edition of this work was published in this JOURNAL for December, 1921. The fact that a second edition has been called for in so brief a period is the best evidence of the merit of the book and of the place that it fills. Though enlarged, the thickness of the book is less than in the case of the first edition, by the use of a thinner but good quality paper. The text is not materially changed from the first edition and what was said of that will apply to the present work. The section on temperature measurement has been omitted in this edition, as the author intends to treat this subject in a separate work under the title "Die Technik der elektrischen Pyrometrie." Important advances that have occurred in the interval between the two editions have been included. Certain rules formed by the Association of German Electricians have been added as an appendix.

HENRY LEFFMANN.

SPACE-TIME-MATTER. By Hermann Weyl. Translated by Henry L. Brose. 324 pages and index, 8vo. New York, E. P. Dutton and Company, 1922.

This book has grown out of a series of lectures delivered at the Zurich Polytechnikum in the summer term of 1917. Its subject is Einstein's Theory of Relativity, that theory which "has advanced our ideas of the structure of the cosmos a step further. It is as if a wall which separated us from Truth has collapsed. Wider expanses and greater depths are now exposed to the searching eyes of knowledge, regions of which we had not even a presentiment. It has brought us much nearer to grasping the plan that underlies all physical happening." The author desired "to present this great subject as an intermingling of philosophical, mathematical, and physical thought, a study which is dear to my heart," but he is constrained to admit that "the mathematician predominates at the expense of the philosopher." The reader, for whom signs of integration and summation, hexaspherical coördinates and vector analysis have no terrors, will find here an interesting and logical development of the theory. From a differential equation he will be led to draw the conclusion that "space is closed and hence finite." He will come to understand why light rays act as if attracted by the sun and, again, what is the basis for holding that a line in the spectrum of sunlight should lie a little nearer to the red than the same line produced upon the earth. In spite of his previous conviction that the force of gravitation is instantaneously propagated he will be compelled to grant that "every change in the distribution of matter produces a gravitational effect which is propagated in space with the velocity of light."

The non-mathematical reader must not infer that this admirable book is of no value for him. On the contrary he will find much of the highest interest. There is, for example, the discussion of non-Euclidean geometry from Proclus onward, but he will in general need to rest content with the conclusions of the mathematical arguments.

To every one who has not assimilated this disturbing theory it will come as something of a shock to read "We are to discard our belief in the objective reality of simultaneity; it was the great achievement of Einstein in the field of the theory of knowledge that he banished this dogma from our minds, and this is what leads us to rank his name with that of Corpernicus." He will be reassured by this "However great is the revolution produced in our ideas of space and time by Einstein's theory of gravitation, the actual deviations from the old theory are exceedingly small in our field of observation. Those which are measureable have been confirmed up to now. The chief support of the theory is to be found less in that lent by observation hitherto than in its inherent logical consistency, in which it far transcends that of classical mechanics, and also in the fact that it solves the perplexing problem of gravitation and of the relativity of motion at one stroke in a manner highly satisfying to our reason."

A valuable bibliography, six pages in length, is given. The volume, as is proper, closes with an index. The fundamental character of the discussion is indicated by the appearance of the terms "earlier and later" and "later" in the list of subjects. We miss any reference to Levi-Civita in the index and, as a reviewer should find at least one error, let it be noted that the reference

to the heat developed according to Joule's Law is to be found, not on page 162, but on the next page.

The translator has rendered the book into good English that rarely, if indeed ever, carries with it the flavor of a translation.

GEORGE F. STRADLING.

ANNUAL TABLES OF CONSTANTS AND NUMERICAL DATA, CHEMICAL, PHYSICAL AND TECHNOLOGICAL. Published under the patronage of the International Council of Research and the International Union of Pure and Applied Chemistry. With numerous collaborators. Volume iv, parts 1 and 2, 1375 pages, 4to. Paris, Gauthier-Villars et Cie., 1921; American distributors, University of Chicago Press.

This enormous collection of data, from the wide fields of chemistry, physics and technology, is a welcome addition to the literature of the science. It represents great labor and care and it is fortunate that the material has been presented in such excellent form and so conveniently classified. The main text is in French but the running heads, which give information as to the special subjects on each page, are in French, German, English and Italian. The use of French probably is the best expedient. German is much too complicated for an international language and Italian is just beginning to make its impression on purely technical literature. It has indeed been prominent in other fields for centuries. It is gratifying to note that French editors have been willing to abandon the eccentricity of writing chemical formulas with the exponents as superiors, which they have so long been doing. The chemical formulas in this work are written as they are in the works of the rest of the world. French chemists gave up some years ago the practise of writing Az for N, but they have held on with persistence worthy of a better cause to the old method of writing atomic numbers.

It is not possible to subject this publication to criticism as would be done with a text-book on science. Its value depends entirely upon the thoroughness of the selection and the care which has been taken to reproduce the data, as found in the numerous authorities quoted. A commendable feature is that, with references, the year as well as the volume is given and the volume is printed in full-faced Arabic type, instead of the Roman letters that are still unfortunately the custom among many scientists, especially those under the spell of British conservatism. It is to be hoped that a volume like this which has such wide uses will be a missionary agent in the reform in bibliographics. Series (if any), year, volume (in full-faced Arabic type) and page; this is the order that should be observed. It is not necessary to put the year in parenthesis, but the series numbers should be in brackets, and, of course, lead off the quotation. An incidental advantage of this volume is that it gives the official equivalents in the four languages of an immense number of technical terms. Students who are acquiring a knowledge of other tongues than their own, will be greatly aided by these data, since, though not so intended, it is a "tetraglot" dictionary. The mechanical execution of the book is good; the type is of the face that is common in French works, not quite so vivid as some of the faces used in English books, but still quite clear. The paper and printing

are commendable. The book takes rank at once among the most valuable reference works of the worker in the physical sciences.

HENRY LEFFMANN.

BELT CONVEYORS AND BELT ELEVATORS. By Frederic V. Hetzel, M.E., Member of A.S.M.E. and The Franklin Institute. New York, John Wiley and Sons, Inc.; London, Chapman and Hall, Ltd. Cloth, 6 x 9 in., 333 pages; half-tones and line cuts. Price, $5 (25s net).

The mechanical handling of materials which lessens human labor is a subject of universal interest but its possibilities and applications are especially the concern of factory managers and production engineers who have handling problems to solve or transportation costs to reduce. The diversified lines of handling machinery now offered, new applications of handling methods constantly introduced and improved types of handling facilities manufactured, make it incumbent upon designing and operating engineers to keep posted on the latest developments in the handling and transportation fields.

Much of the literature published on this subject is too general or too limited in scope, largely descriptive and often fails to include general principles, economic considerations, or the basic data needed. A commendable contribution to recent technical literature, which is exceptionally thorough in its treatment of its subject, is "Belt Conveyors and Belt Elevators."

As chief engineer for thirteen years after a previous service as chief draughtsman for Link Belt Company, Mr. Hetzel was responsible for the design of many varieties of elevating and conveying machinery and acquired a wide experience and thorough knowledge of material handling equipment.

His new book is a thorough and practical treatise and presents for the general use of engineers and manufacturers specialized information, useful data and working formulæ which are not included or conveniently presented in trade catalogues and not widely known outside of the material-handling field. The book covers recent developments in both American and European practice. The information is impartially presented with no "axe to grind" and points out the merits of equipment for a particular service without attempting to boost the product of any favorite manufacturer.

The principles and reasons underlying the design, applications and service of belt conveyors and belt elevators for different classes of materials are fully discussed. The book is well illustrated with detail drawings, photographic views and charted curves. Tables of sizes, capacities, power consumption and other useful data are present in convenient form for engineers or manufacturers who have handling problems to solve. The text is concisely written, with frequent cross-references as well as mention of other sources of information. The book is a worthy and useful contribution to material handling literature.

HAROLD T. MOORE.

THE MICROSCOPICAL EXAMINATION OF FOODS AND DRUGS. By Henry Greenish, F.I.C., F.L.S. Third edition, xx–379 pages, index and 209 illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1922. Price, $4.50 net.

This is a compact volume covering all the important data relating to the examination of commercial drugs and foodstuffs, as far as the microscope is

employed in such work. The many illustrations will give the student and analyst vivid ideas of the appearance of the substances. All the illustrations are drawings, but they have been carefully made, and, while necessarily somewhat schematic, are satisfactory. Brief directions are given for the preparation of specimens for the microscope, and an appendix gives a list of solutions commonly employed. It is to be noted that the spelling "gramme" is employed, and the persistence with which the British hold on to this unnecessary method is discouraging to those who would like to simplify English spelling. However, recent works on chemistry that have emanated from British presses have shown a slight reforming tendency, and we may hope that in time the spelling "gram" will be usual. Those already fairly familiar with the technic of the microscope will find the work useful in detecting adulterations and determining the nature of powdered vegetable substances. The book is clearly printed on paper of moderate quality and its compactness makes it especially suitable for the student.

HENRY LEFFMANN.

HANDBOOK OF THE CENTRAL HIGH SCHOOL OF PHILADELPHIA. 132 pages, 17 illustrations, 8vo. Philadelphia, The Barnwell Foundation, 1922.

This book has been prepared and printed for distribution among the students and graduates of the Central High School by the Mary Gaston Barnwell Foundation, established under the Will of James Gaston Barnwell, A.M., a member of the sixteenth class, which graduated from the school in July, 1850. In his Will he wrote:

"Whatever reputation and success I have attained, however moderate, being the result, under Providence, of two causes, first, the training of a good mother who always inculcated and practiced the highest principles of honor and especially of moral courage regardless of immediate or apparent results, and secondly, to the education which I received in the Public Schools of Philadelphia and especially in the Central High School, I wish to honor the memory of that mother by practically encouraging and rewarding the practice of the same high principles by the Students and Graduates of the School."

While the handbook is primarily for the Central High School student and alumnus, yet it contains much information of general interest, for this institution, since its founding, has been in fact, as it should be in name, the city college, and, since 1849, has possessed the full powers of a university by Act of Assembly. Lists of notable teachers of the past and of representative alumni of every class contain the names of many men who have attained eminence in the various fields of science, and include many members of The Franklin Institute. The first president of the school was Alexander Dallas Bache, the great-grandson of Benjamin Franklin. The astronomical observatory was the fourth to be established in the United States. The inventions of Edwin J. Houston and Elihu Thomson in the field of electricity were developed in the laboratories of the school.

In the pages devoted to student organizations, reference is made to the work of The Natural History Society, The Chemistry Club, The Radio Club, The Camera Club, The Astronomical Society, and The Geographical Society, showing that the deep interest in things scientific still pervades the student body.

JOSEPH S. HEPBURN.

PUBLICATIONS RECEIVED.

The Theory of Emulsions and Emulsification. By William Clayton, D.Sc. 160 pages, illustrations, plates, 8vo. Philadelphia, P. Blakiston's Son and Company, 1923. Price, $3.

Industrial Organic Chemistry, adapted for the use of manufacturers, chemists, and all interested in the utilization of organic materials in the industrial arts. By Samuel P. Sadtler, Ph.D., LL.D., and Louis J. Matos, Ph.D. Fifth edition (revised, enlarged, and in part rewritten). 691 pages, illustrations, plates, 8vo. Philadelphia, J. B. Lippincott Company, 1923. Price, $8.

Plastics and Molded Electrical Insulation. By Emile Hemming. 313 pages, illustrations, plates, 8vo. New York, The Chemical Catalog Company, Inc., 1923. Price, $5.

Practical Physiological Chemistry. A book designed for use in courses in practical physiological chemistry in schools of medicine and of science. By Philip B. Hawk, M.S., Ph.D. Eighth edition, revised. 693 pages, illustrations, colored plate, 8vo. Philadelphia, P. Blakiston's Son and Company, 1923. Price, $5.

The Quantum Theory. By Fritz Reiche, Professor of Physics in the University of Breslau. Translated by H. S. Hatfield, B.Sc., Ph.D., and Henry L. Brose, M.A. 183 pages, illustrations, 12mo. New York, E. P. Dutton and Company, no date. Price, $2.50.

Institut International de Physique Solvay. Atomes et Électrons. Rapports et discussions de Conseil de Physique tenu a Bruxelles du 1er au 6 Avril, 1921. Publiés par la Commission administrative de l'Institut et MM. les Secrétaires du Conseil. 271 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1923. Price, 20 Francs.

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CURRENT TOPICS.

Liquid Oxygen in Warfare. SIR JAMES DEWAR. (Royal Institution of Great Britain, 1919.)—The members of the Royal Institution of Great Britain were engaged in research work for the British Government during the late war and one of the lines in which investigation was extensively carried on was the use of liquid oxygen. Professor Dewar, being especially qualified by extended researches, was directly engaged in this line and on January 17, 1919, presented a communication at the Weekly Evening Meeting of the Institution, giving an account of some of the more novel and important applications made.

The liquefication of oxygen in the laboratories of the Royal Institution in 1884 was followed by the introduction of commercial methods for obtaining liquid air from which oxygen was subsequently obtained. The manufacture reached the amount of about one hundred twenty tons of liquid air per day, more than half of which was used in the oxy-acetylene blowpipe for cutting armor plates and welding. This work was carried out largely by the British Oxygen Company.

In this process a large amount of nitrogen was obtained which was practically useless, but very soon processes for its fixation in the form of important compounds were devised. The German dye industry spent large sums for securing water-power in Sweden in order to use the electric methods of fixation. These industries, however, pursued the problem along a much different line and finally developed, under the guidance of Haber, the now well-known process of direct union of nitrogen with hydrogen under very high pressure by the aid of a catalyst. Very large plants were erected in Germany for this purpose and it is probable that if such methods had not been well developed, Germany would have been unable to obtain the chemicals necessary for the manufacture of high explosives in the amount needed in the war. The Haber process yields ammonia directly which may be converted easily into nitric acid.

The lecture proceeded to describe the general characteristics of liquid oxygen. In the spectroscope three well-defined bands are seen in the orange and green. It is highly magnetic and shows very strikingly the spheroidal state. The use for explosive purposes which has now become of considerable importance is easily illustrated by soaking some cotton in liquid air and applying a light. The mass burns with a brilliant flash like gun-cotton. Finely divided organic matter mixed with liquid oxygen can be used for blasting when packed into a rock boring and detonated by an electric discharge. It has the advantage of retaining its explosive properties only

for a short time with consequent absence of danger from any unexploded charge.

An important war-time application of liquid oxygen was to supply oxygen gas for airmen at high altitudes and also for treatment of "gassed" cases in trench or hospital. For this purpose the liquid was volatilized from some form of vacuum container by regulated influx of heat, whence the gas was conveyed by tubes to mouth-pieces for breathing. Apparatus of this kind was found in German aeroplanes brought down when raiding London. This method has the advantage over that of carrying the necessary oxygen compressed in steel cylinders, in that it is much lighter to carry, and less cumbersome.

Three methods were devised for this purpose: Syphon evaporation, electrical heat evaporation and metallic heat conduction. These methods were described and illustrated in the lecture and the conditions under which they are best applied detailed. It appears that success attended the various methods adopted. The problem of evaporation of the liquid air from vessels in a vertical position is easier of solution than when the vessels are liable to be in other positions. The use of the vacuum containers when liable to movement from the vertical position would result in the liquid being splashed about, but by packing the interior with a suitable absorbent, this does not occur. Several inert materials were tested as to their adaptability. These included forms of charcoal, asbestos, sponge and siliceous earth, commonly called kieselguhr. The experiment showed that asbestos and the siliceous earth absorbed the largest amounts of liquid. Careful comparisons between these indicated very markedly that asbestos was by far the most economical material, since the charged substance has only two-thirds the weight of the siliceous material when carrying the same weight of liquid oxygen. These masses of absorbed oxygen when in a vacuum vessel retain a constant temperature and a constant rate of boiling, until almost the last trace of liquid is gone.

Liquid air, as usually obtained, is not uniform in composition, ranging between 34 per cent. of oxygen to almost 100 per cent. The former mixture boils at 80° absolute temperature, the latter at about 90°. The mathematical and physical data in regard to these problems are presented at considerable length.

In the early days the use of cooled charcoal was studied, and it was found that only when the charcoal was free from volatile substances could high efficiency be obtained. In this connection the American work as to the nature of charcoals, by Chaney and his associates, is of interest. Tests were made as to the efficiency of vacuum containers, and it was found that there is little advantage in increasing the capacity above about 30 kilos for storage purposes, at which size the limiting efficiency of about 5 per cent. loss of total capacity per day is reached. In aviation about 5 litres

would be the useful mean size for supplying three or four persons, even though there might be one or two days' delay between the delivery of the liquid and its use. H. L.

Detection of Hypochlorites and Chloramins in Milk and Cream.—These substances being now largely used in dairy work for disinfecting utensils, it is not at all unlikely that they may be added to milk intentionally, or be accidentally introduced. Philip Rupp, Dairy Chemist, Bureau of Animal Industry, has investigated the tests for such substances in market milk, and his results have appeared in a bulletin of the department. For sake of brevity he uses the term "chlorine" for the available chlorine in the compounds. The detection of such chlorine in water is easy, by means of the starch-potassium iodide or ortho-toludin test, but in dealing with milk there are interferences owing to the union of the chlorine with the proteins. It was found, however, possible to liberate the chlorine so that it will react with potassium iodide. Mixtures of pure milk and cream were made with definite small amounts of hypochlorites and chloramins and set aside in an ice-box for 48 hours. These were tested for chlorine, allowed to stand for several hours at room temperature, returned to the ice-box for 48 hours and again examined. A flask of pure, untreated milk was employed as a control.

The reagents are:

Seven grams of potassium iodide in 100 c.c. of water. This should be fresh.

One hundred c.c. of concentrated hydrochloric acid are diluted with 200 c.c. of water.

One gram of starch is boiled in 100 c.c. of water and cooled.

Distilled water should be used.

The test is applied as follows:

Five c.c. of the sample are placed in a medium-sized test-tube, 1.5 c.c. of the iodide solution added, the mixture shaken and the color carefully noted. If no perceptible color change appears, 4 c.c. of the dilute hydrochloric acid are added and the curd thoroughly stirred with a glass rod flattened at the end. The color is again noted. The tube is then placed in water at a temperature of 85° C. and allowed to remain 10 minutes, the temperature being maintained at the original point. It is then rapidly cooled in water, and again examined for color. Finally, 0.5 to 1 c.c. of the starch solution is added to the liquid below the curd and the reaction noted.

Milk containing 1 part of chlorine to 1000 acquires a distinct reddish tint and at a dilution of 1 to 2500 is still slightly colored as compared with the control. This statement applies to both hypochlorites and chloramins. With 1 part of chlorine to 5000 parts of milk, the liquid acquires a pale yellow on addition of the iodide solution. These data relate to samples not heated during the test. When the heating is applied the delicacy of the reaction is increased, so that 1 part of chlorine in 50,000 parts of sample may be detected.

Milk kept in the ice-box for 48 hours still gives the test. When kept at room temperature the delicacy of the test is not so great. Milk pasteurized at 145° F. reacts like raw milk, 20 per cent. cream reacts like milk. It is best to examine carefully the curd and liquid below it.

H. L.

Telephonic Speaking and Hearing. MARAGE. (*Comptes Rendus,* Oct. 23, 1922.)—"This note leads to the same results as those indicated by Mr. Fletcher in the JOURNAL OF THE FRANKLIN INSTITUTE, June, 1922, page 729, of which a résumé appeared in the *Revue générale des Sciences* for September 15–20, 1922. This agreement is interesting because the processes employed are entirely different."

Known facts of experience—(1) The ear is much more sensitive to sounds of high than to those of low pitch, or less energy is needed to make audible a sound of high pitch than one of low pitch.

(2) No two ears are entirely alike because the cerebral auditory centres interpret the vibrations affecting the ear.

(3) Hearing is no more fatiguing than breathing or digesting. It is listening that causes fatigue, because then the brain comes into play.

Owing to the high pitch of their voices women and children have an advantage in making themselves heard over the telephone. But being heard is not enough. It is necessary for comprehension that vowels and consonants be clearly distinguished. From a photographic record of the word "bonjour," presumably pronounced by a Parisian, it is concluded that the duration of the consonants is only one-twelfth of that of the vowels. The consonants do not have in French a fair chance to produce an impression. When an analysis is made of "le roulement du tonnerre," pronounced by a person from the Midi, quite a different division of time is found. The duration of the consonants is to that of the vowels as 4 to 3. The writer draws, of course, for France, the conclusion "Other conditions being equal, for telephone operators, we should select inhabitants of the Midi who make their consonants to be heard as well as their vowels." One who has spoken with a man from Vaucluse might, however, doubt the wisdom of this suggestion.

Both the *d* and the *t* appear to have no detectable duration. "It is a rare thing to find among telephone operators a sense of hearing, I will not say fine, but even normal. Is this due to the fatigue produced by prolonged use of the telephone? Perhaps this is so, since there is in this occupation brain work very great in amount and all the greater because the public speaks too rapidly, pronounces badly and listens badly." All the above is related to the use of the telephone in speaking. In order to obtain data on transmission of the singing voice, Professor Marage had his pupils at the Sorbonne record their impressions of a concert given at the Eiffel Tower and heard by them by means of the wireless telephone. The

notes were very accurately transmitted. Men's voices are better understood than those of women. Resonators augmenting the volume of sounds at the same time modify them to a great extent.

G. F. S.

The Effect of Dissolved Substances on the Deposition of Colloidal Particles from a Solution by Means of an Electric Current. R. D. KLEEMAN. (*Phys. Rev.*, Sept., 1922.)—Porcelain slip is a colloidal solution in water of particles of flint, feldspar and clay. "During some experiments on the electric deposition of porcelain slip it was observed that the deposit obtained from the slip used in the wet porcelain process was solid though not quite dry, while that obtained from slip used in the dry process was of the consistency of thick cream. It was soon found that the difference in the nature of the deposits obtained was due to the small quantity of sodium silicate (Na_2SiO_3) that is mixed with the slip used in the wet process. It was found that besides sodium silicate the substances Na_2SO_4, Na_3PO_4, Na_2HPO_4, H tartrate, Na tartrate, NaOH, KOH showed the effect very well, and in fact it was found that most substances showed the effect in a more or less degree." The compactness of the deposit in general increases with the quantity of substance added though with a small added amount (one part in from 300 to 1000 by weight), the maximum effect is attained, and further increase produces no noticeable result. The current density seems to be without effect on the hardness of the deposit, unless sufficient gas is evolved to interfere with the process.

There is a connection between the foregoing effect and the following. Let a slip be taken which holds 30 per cent. of solid matter by weight. To this add one three-hundredth of Na_3PO_4. Solid matter will be deposited, mostly feldspar and flint. This precipitate will, however, go again into solution upon the addition of further solid matter. When enough of this has been added to make the fluidity the same as before the introduction of Na_3PO_4, the slip will be found to contain about twice as much solid matter as before.

"Both effects may be explained if we assume that the radii of the spheres of action of the particles of the slip are diminished by the dissolved substance. It is concluded that the volume of the sphere of action of a particle in porcelain slip is about double the actual volume."

G. F. S.

Progress in Nitrogen Fixation.—The annual report of the United States laboratory for research on nitrogen fixation gives a summary of the work accomplished in the fiscal year ending June 30, 1922. The laboratory is under the direction of Doctor Cottrell, and is in the Department of Agriculture. The importance of the procedures for nitrogen fixation is pointed out. Three of these are at

present prominent: Direct union by the arc, production of cyanamide and synthesis of ammonia. Several others, Buchner (alkali-cyanide), Serpek (aluminum nitride) and Häuser (explosion) have been investigated and operated on fairly large scales, but cannot yet be considered commercially established. In the United States at present nitrogen compounds cannot be made by fixation at prices that will compete with Chile nitrate and ammonia from coal coking, except under unusually favorable circumstances. The special problem before the research worker in this field is to reduce the cost of the fixation methods. The synthetic ammonia (Haber) process is the one that presents especial advantages and difficulties. The principal difficulty is to secure a catalyst that may be easily obtained in quantity and that is not very sensitive to impurities. The laboratory has had considerable success in this line. The production of pure hydrogen and the discovery of a material for the containers have been also studied with encouraging results. Ordinary carbon steel soon deteriorates under the conditions in which the gases are combined. The development of apparatus capable of bearing a much higher pressure has been undertaken, inasmuch as combination is greatly favored by increasing pressure. Studies of the cyanamide method have not so far indicated any considerable reduction of cost. The arc method has the advantages that it can be installed rapidly and delivers the nitrogen directly in the oxidized condition. The direct cyanide (Buchner) method has not been successfully developed on a commercial scale. The chemical and engineering features require further study. There is some doubt whether the product of the cyanide process can be converted cheaply into fertilizing material, but it must be borne in mind that the recent application of hydrogen cyanide as a fumigating agent for fruit trees has developed a new and rapidly growing market.

Comparatively little information is at hand as to the agricultural value of many of the compounds obtained by nitrogen fixation, for which reason an experimental farm has been installed. Interesting and valuable results have already been obtained and are being prepared for publication. H. L.

On the Minimum Potential for Electrical Discharge in Gases at Low Pressures. E. DUBOIS. (*Comptes Rendus.*)—In a former investigation the author made known singular variations of potential found by him in studying electrical discharges in hydrogen at low pressure. At that time he attributed these to the presence of gas occluded by the electrodes. More recently he has used platinum, tungsten and molybdenum as electrodes and now he concludes that the variations of potential are to be ascribed to the occurrence of saline substances upon the electrodes.

Let the two electrodes be fresh pieces of the same metal (state A) and let the difference of potential for disruptive discharge be determined. Now let both electrodes be heated to white heat in a vacuum for several seconds. A greater difference will be subse-

quently required for discharge than was previously the case. If alternate heatings and measurements be made, it will be found that the difference of potential tends rapidly toward a limit corresponding to a new state of the metal (state B). For all three metals mentioned there is a potential difference greater by about 100 volts needed for discharge with state B than with state A. If one of the electrodes is in state A, while the other is in state B, it is the cathode which determines whether the higher or the lower difference of potential must be applied to get discharge.

The explanation offered by the author is that passage of a metal from state A to state B is due to the disappearance of some substances or mixture of substances from the cathode. The following experiment bears out this interpretation. Take two electrodes in state B. On one put traces of potassium chloride. Upon making this electrode the cathode the experimenter finds that the potential difference sinks to that corresponding to state A, but, if he makes the soiled electrode the anode, the P.D. for state B will be required for discharge.

To cause the difference of potential to decrease to a notable extent no more than a millionth of a gram of salt per sq. cm. is requisite on the cathode.

The number of volts measuring the difference of potential for discharge is the same within the error of experiment for all three metals in gases at the same pressure.

The nature of the metal, therefore, seems to make no difference. It is possible to make a metal pass from state A to state B by causing an intense discharge to pass between the electrodes for some time. G. F. S.

Note on Overblown Pipes. S. BHARGAVA and R. N. GHOSH, Muir Central College, Allahabad, India. (*Phys. Rev.*, Nov., 1922.)—When an organ pipe is blown the fundamental tone is obtained when a certain pressure of air is used. If this pressure be increased, not only does the sound grow louder but its pitch likewise rises. At one pressure the octave of the fundamental is heard for the first time. As the pressure continues to increase this octave grows more and more prominent and later the pipe settles down to the production of this tone.

By means of a Phonodeik these Indian experimenters have measured the change of pitch with increasing pressure when the blowing lip was .8 cm. from the edge of the pipe, with the following results where pressures are given in heights of the water column and pitches by the frequencies of the tones: 6 cm., 490 (the fundamental); 10 cm., 495; 20 cm., 500; 32 cm., 505; 38 cm., 1050 (octave), and 50 cm., 1052. "At about 30 cm. of water the octave is clearly heard with the fundamental." The great rise in pitch from 32 to 38 cm. is due to the extinction of the fundamental at

the higher pressure. At lower pressures the octave is present, but it is subordinate to the fundamental.

Similar studies were made with the lip at different distances from the edge. In all the same succession of phenomena was noted. The greater the distance from lip to edge the higher the pressure requisite to elicit the fundamental, and the same is true for the octave. It requires six times as much pressure to evoke the fundamental when the distance is 5 cm. as when it is 1 cm., but for the octave the ratio needs to be made twenty for the same change of distances.

After the octave has been obtained, further increases in blowing pressure have but little effect in raising the pitch. The hydrodynamic problem related to the blowing of a pipe is by no means completely solved, but this modest contribution has helped to clarify certain features of it. G. F. S.

Evaluation of the Intensity of Vertical Electrical Currents Leaving the Surface of France. C. MAURAIN and MRS. DE MADINHAC. (*Comptes Rendus.*)—Let a closed curve be traced on the surface of the earth. Around this contour integrate the expression $H \cos\theta \, dS$, where H is the horizontal component of the earth's magnetic field, θ is the angle of this component with the contour and dS is an element of the contour. The integral should be zero, provided the magnetic field depends upon a potential. If it is not zero, the presence is indicated of an electrical current passing vertically through the surface embraced by the contour. The integration was applied to a part of France having an area of 415,100 sq. km. The integral was not zero but had a value showing a vertical current of 1800 amperes, or .0043 ampere per sq. km.

L. A. Bauer studying the same problem for the entire earth has inferred for regions between the north pole and latitude 45° north electrical currents directed upwards and of strength .026 ampere per sq. km., and, from the latitude named to the corresponding south latitude, currents flowing downwards of strength .010 ampere. France is not far from the latitude where these currents change their direction, hence their small value for this country.

G. F. S.

Testing of Foodstuffs for Vitamins is described by J. C. DRUMMOND and A. F. WATSON, of University College, London (*Analyst*, 1922, xlvii, 235–246). Physical and chemical methods do not exist for the detection and determination of the vitamins, so they must be studied by the biological method, *i.e.*, their action on animals. Fat soluble A, which promotes growth and prevents the eye disease known as xerophthalmia, accompanies the unsaponifiable fraction of a fat, provided the latter be isolated under conditions which exclude oxidation. A daily dose of approximately 0.01 milligram of this vitamin, as it occurs in cod-liver oil, is sufficient to produce nearly

normal growth in an albino rat. The traces of this vitamin, which occur in casein, are destroyed if that protein be spread out in thin layers and be exposed for several hours to a temperature of 110° C. in a current of air. In testing for water soluble B, determination of the growth curve of the rat is preferred to determination of the curative effect on a polyneurotic pigeon. Commercial yeast extracts are especially rich in this vitamin. In the past, food control officials have tested meat extracts for adulteration with yeast extract; in the future, they probably will have to combat adulteration of the vitamin-rich yeast extracts, with less potent materials. In testing for the antiscorbutic vitamin, water soluble C, use is made of the guinea-pig. Lemon juice is a far more potent antiscorbutic than lime juice.

J. S. H.

A Resistance Furnace with Molybdenum Wire. P. FLEURY. (*Comptes Rendus,* Nov. 13, 1922.)—A temperature of more than 1700° C. can be maintained in a cylindrical space several centimetres in diameter and several decimetres in length by sending the electric current through a spiral of molybdenum wire wrapped about a refractory, insulating support. This metal is preferred to tungsten, though it is more volatile and more fusible than the latter, because it is less costly, more lasting and easier to wind. The furnace was maintained in a vacuum. When the insulating material, alundum, was heated up for the first time, it disengaged gas that attacked the molybdenum. To avoid this the heating needed to be so slow that the gases could be removed as soon as they appeared. Thus at the first heating it took several days to attain 1500°. After this a much shorter time was required. The alundum is melted in this furnace, when the current gets too strong, but the metal wire stands the temperature well and can probably be raised to higher temperatures if supports of cast magnesia or zirconia be used. G. F. S.

Elasticity and Symmetry of Quartz at High Temperatures. ALBERT PERRIER and B. DE MANDROT. (*Comptes Rendus,* Oct. 16, 1922.)—Certain hypotheses on the nature of piezoelectricity led one of the authors to predict the disappearance of this phenomenon in the case of quartz for some temperature. This was found by experiment to be 576° C. It remained to investigate the temperature relations of the elasticity of the crystal, the other element entering into piezoelectricity. Plates of quartz, from 70 to 80 mm. in length, were supported near the ends and weighted at the middle. Considerable difficulty was met in connection with the elevation of temperature and with the fragility of the plates at the temperature of transformation.

Young's modulus in kg. per sq. mm., parallel to the optical axis is 10,480 at 18°. As the temperature rises it diminishes at first slowly, then more rapidly as 576° is approached, 572°, 6960; 574°, 6510; 574.5°, 6320; 575°, 6020; 576°, 6680; 577.5°, 9060.

From this temperature onward the modulus continues to increase until it reaches the value of 9910 at 1078°. In directions perpendicular to the optical axis the effects of temperature are even more marked: 18°, 8010; 573°, 3570; 574°, 3210; 576°, 9030; 585°, 10,530; 1140°, 12,190.

With regard to the effects of both force and temperature upon the crystal a complete reversibility was found, except that near the transformation point several minutes were needed for the attainment of the figure of equilibrium.

In connection with the variations of the modulus with temperature it is interesting to note that up to the transformation temperature all dimensions of the crystal grow longer with rise of temperature, while above that point they contract.

A study of the modulus along two directions making 50° with the optical axis leads to the conclusion that at 576° the crystal passes from rhombohedral to hexagonal symmetry. G. F. S.

Vapor Tension of Some Copper-zinc Alloys in the Solid State. L. GUILLET and M. BALLAY. (*Comptes Rendus*, Nov. 27, 1922.)—When brass is heated, the volatilization of the contained zinc begins. This is found to be greatly influenced by the nature of the surrounding gas, whether oxidizing, neutral or reducing. A brass of composition, copper 55.20 per cent., zinc 44.75 per cent., iron .02 per cent., was used. This was heated for six hours in different gases circulated in the same manner. With air .15 per cent. of the weight of the specimen was lost when the temperature was kept at 650° C. and 1.19 per cent. when at 800°. A film of oxide formed and hindered the process of volatilization. In nitrogen at the temperature of 800° the loss was 7.88 per cent., in CO at 808° 10.58 per cent., in hydrogen at 800° 10.57 per cent., and in the same gas at 600° only 1.09 per cent.

The vapor tension of the solid brass in millimetres of mercury was found to be 3.33 at 540°, 5.09 at 560°, 6.90 at 575°, 11.20 at 600° and 19.30 at 630°. G. F. S.

The Effect of Temperature on the Scattering of X-rays by Crystals. G. E. M. JAUNCEY. (*Phys. Rev.*, Nov., 1922.)—When X-rays are regularly reflected from the surface of a crystal, a part of the incident beam is at the same time diffusely scattered. A crystal surrounded by a heating box having mica windows received on one of its faces a beam of X-rays from a Coolidge tube. The strength of the diffusely reflected beam was measured by an ionization chamber. Observations were made with the crystal at 17° C. and again at 295° C. For rocksalt the scattered intensity at the higher temperature was 1.33, or 1.18 times as great as at 17°, according to the angle at which the scattered radiation was received. For calcite the change of temperature made little or no difference. The results are in only very crude agreement with Debye's theory of this effect. G. F. S.

A Boat Which Sails into the Teeth of the Wind by Using the Wind Itself as Motive Power. CONSTANTIN, JOESSEL and DALOZ. (*Comptes Rendus,* Oct. 23, 1922.)—Sails will not suffice for this. The solution was found by using an air turbine geared to a screw in the water. The combination was mounted on a fishing boat. The air turbine, with two blades and devised for minimum weight, was 9 m. in diameter. The screw had four blades and was 1.05 m. in diameter. In both the inclination of the blades was variable. The setting of the turbine perpendicular to the wind was made by the steersman through an endless screw gearing. "The boat thus equipped showed itself very manageable. One man was enough to bring it from Sevres to Saint-Cloud in the midst of the active shipping of the Seine and in spite of the current of the river. It could be handled in just the same way as a boat with a thermal motor." The boat could progress in any direction to the wind.

The wind acting on the turbine located a considerable distance above the water produced a force tipping the boat over. This was counteracted by a deeper keel.

It might seem that the forward thrust of the screw could not be greater than the backward push of the wind on the turbine. With suitable dimensions of the turbine and screw and with a proper transmission with multiplication of the angular velocity of the former to the screw, the forward thrust may, however, be made the greater. G. F. S.

The Electric Arc as Rectifier. STANISLAW BOROWIK. (*Physikal. Z.,* Sept. 15, 1922.)—In studying the alternating current arc it was found that an arc, one of whose electrodes was covered with iron oxide while the other was carbon, allows only that phase of the alternating current to pass for which the oxide is positive. This phenomenon regularly manifested itself for current strengths ranging from 2 to 30 amperes and for voltages from 100 to 1500. Somewhat similar results were obtained for the current from an induction coil.

It is interesting to note that this paper comes from a laboratory in Petrograd. G. F. S.

Distribution of Methyl Anthranilate in Grapes.—Power and Chesnut showed some years ago the existence of this ester in many samples of grape-juice and devised methods for its detection. They have extended their researches in order to determine whether the ester occurs in all forms. Their results have just been published in *Jour. Agric. Res.* (1923, v. 23, 47). Although the cultivation of the vine and the utilization of its juice for the manufacture of an intoxicating beverage dates from the earliest period of which we have written history, the genus *Vitis* is more developed in the New than in the Old World. The Old World vine is *V. vinifera* L, and even at this day, this species, developed into many varieties, is exclusively cultivated. The most commonly cultivated American species is

V. labrusca L, a typical representative of which is the Concord grape. Another form much esteemed is *V. riparia Michx,* which is the original of the Clinton grape. In the South, *V. rotundifolia Michx,* best represented by the Scuppernong or Muscadine, and *V. æstivalis Michx,* represented by the Norton grape, are principally in use.

Authentic samples of grapes from many sources were tested, and it was found that when the plant was derived from *V. labrusca* or hybrids in which this predominated, methyl anthranilate was present, but the fruit of *V. vinifera* does not give evidence of it. It appears that this species does not thrive in the United States, east of the Rockies, but is very successfully cultivated in California. The great grape-growing industry of that region is said to depend upon the cultivation of the European species. The literature of grape-culture shows that about 6000 varieties have been described. Even in California, however, many of the vines are growing as grafts on American roots, and it is thought probably that in time all the vines will be thus grafted. A number of samples of commercial grape-juice were tested, most of which contained the ester.

H. L.

Oxidized Kerosenes as Fuel.—This problem has been undertaken at the laboratories of Carnegie Institute of Technology, Pittsburgh, in experiments to determine the relative efficiency of kerosenes and oxidized kerosenes as fuels. According to a report by Dr. J. H. James, Head of the Department conducting the experiments, oxidized kerosenes cause less "knocking" tendencies than the straight when used in a kerosene engine, but have approximately the same power development notwithstanding that the thermal value is one-eighth less. Doctor James attributes this efficiency to the better "clean up" in the combustion of them.

The experimental work at Carnegie gives promise that oxidized kerosene, which is manufactured by catalytic oxidation from low-grade petroleum, may become a useful fuel. H. L.

Studies of Vitamins.—At a recent meeting of the Royal Institution of Great Britain, Dr. Arthur Harden presented a summary of present knowledge on the question of vitamins. Experiments on these substances are difficult and tedious. It seems to be established that vitamins A and C are fairly resistant to moderate increase of temperature provided air is excluded, but deteriorate rapidly when exposed to oxidation. Vitamin B is less affected by heat and aeration. All three vitamins originate in the vegetable kingdom, and in view of this fact, it is interesting to recall the Biblical endorsement of the "green herb for meat" as given to the residents of Gan-Eden. In fats, the vitamin seems to reside entirely in the unsaponifiable portion, and as this usually consists largely of cholesterol, which has no value, it is evident that the amount of the really active substance is very minute. Vitamin A does not appear until the photosynthetic actions occur. Vitamin C is not in seeds, but appears when they

germinate and before any green parts are formed. The conditions under which vitamin B is produced are still somewhat uncertain, but its existence in yeast shows that it may be produced without action of light. Milk from stall-fed animals is poor in A and also likely to be deficient in C. The comparatively enormous amount of A in cod-liver oil has been one of the most striking results of recent investigations, but in connection with these data the fact that liberal exposure to sunlight will often counteract certain dietetic deficiencies must not be overlooked. It must not be forgotten that most of these feeding experiments are conducted in laboratories not open freely to sunshine and that the animals are under decidedly unnatural conditions in some ways. H. L.

The Radioactivity of Springs Near Bagnoles-de-l'Orne and Its Relation to Geological Structure. P. LOISEL. (*Comptes Rendus.*)—This region is about 100 miles west of Paris. The springs occur in groups distributed along lines running from northeast to southwest and following the general structural lines of the region. Those springs, whose radium content is greater than one millimicrocurie per litre, with a single exception, are arranged along a syncline of sandstone. To the south of these is a second group, emerging from granite and containing less radium than the first. Still further to the south is a third group with even less radium content. To the north of the first group the radioactivity grows less with increasing distance from this group. In the extreme north of this region is a spring with a high content of 1.83. The cause of this anomaly is not yet known. Those springs whose waters come from merely superficial layers have only a slight radioactivity or none at all. In the chief spring the content in a year diminished to .735 from .980 millimicrocurie per litre. The effect of rain is to cause a prompt increase in the radium content.

There appears to exist a close connection between the geological formation from which the spring issues and the radioactivity of its waters. G. F. S.

Lightning and Trees. V. SCHAFFERS. (*Comptes Rendus,* Nov. 27, 1922.)—In order to explain the immunity from strokes of lightning enjoyed by certain species of trees recourse has been had to the quiet, preventive discharge that takes place because of the pointed or jagged form of the leaves or because of the hairs growing on the leaves. The author conducted a series of experiments to determine the effect of leaves on the electric discharge. A healthy leaf, freshly picked, was placed 2 cm. from an insulated disc charged positively by an electrical machine. Both the leaf and the negative terminal of the machine were joined to earth. The potential difference was raised until the silent discharge set in between leaf and plate. The values range in volts from 3190 for acacia to 10,550 for alder. Statistics of the relative numbers of different species of trees struck by lightning in Belgium and

also in Styria and Carinthia are given, but there seems to be little or no parallelism between these statistical results and the proportions that might be expected to hold in view of the experiments. It is true that alder leaves require the highest potential difference and might for this reason be expected to experience the least protection as a result of the silent discharge and therefore to be struck most frequently. As a matter of fact they were but rarely struck either in Belgium or in Austria. This may be due to the low height attained by the tree. In Belgium poplars were struck eight times as frequently as resinous trees, while in the two Austrian provinces resinous trees were struck four times as often as poplars.

When grass was substituted for leaves in the experiment, 2490 volts only were needed, whereas the gilded points of a lightning rod required from 8510 to 9810 volts. G. F. S.

A Study of the Effect of Adsorbed Gas on the High-frequency Resistance of Copper Wire. AUSTIN BAILEY. (*Phys. Rev.*, August, 1922.)—"At very short wave-lengths, measurements made of the high-frequency resistance of a one-metre square loop of wire show a much larger value than that calculated from the formula for the resistance of a straight wire of the same length." For 18 B. and S. gauge copper wire the measured resistance for waves 30 m. in length is more than three times as great as that calculated from the formula. Since in accordance with the skin-effect a large part of the current will flow through the peripheral portions of the wire, any modification of those parts will be of significance in connection with the discrepancy in resistance.

"A square loop, 60 cm. on a side, was formed by enclosing copper wires inside of glass tubes connected to a vacuum pump, and after several hours' preliminary heating and pumping, the wire was glowed, and then its resistance for radio-waves of 20 metres' length was found to increase in 20 minutes by several per cent., though the residual pressure was only 10^{-5} atm. After successive glowings the effect became progressively less as the oxide layer disappeared. With higher pressures the increase to an equilibrium value came more rapidly. These results indicate that the gas adsorbed by the copper-oxide layer does increase the resistance, and suggest that possibly copper wire, whose surface is covered with a thin layer of metal such as tin, might have a lower high-frequency resistance than oxidized copper wire of the same size." Such a covering metal should neither oxidize readily nor adsorb gases. G. F. S.

Practical Applications of Ultra-violet Light.—Considerable difference is observed as to the fluorescence of substances under ordinary light and light not visible to human eyes. Studies have been made by several observers, those published a few years ago by Wood having been among the most interesting. The most recent investigations are those made in the laboratory of physical chemistry at the University of Upsala, an account of which appears in the current

issue of the *Photographic Journal* (1923, vol. 63, 30). The work was carried out by Svedberg and Andersson. In 1915, Kögel worked out a method of deciphering palimpsests by taking advantage of the fact that the portions of the parchment on which erasures had been made do not fluoresce under ultra-violet rays as do the unaltered portions. A palimpsest is a manuscript from which the first writing has been removed by mechanical means and the sheet then written over with new matter. Several very valuable manuscripts have been treated in this way and the recovery of the original text has been very desirable. An important manuscript in the library at Upsala was lately photographed by Svedberg and Andersson by illuminating the sheet with two quartz lamps giving about 3000 c.p. each enclosed in light-tight houses, provided with windows glazed with Wratten UV filters. As the intention is to photograph the sheet with the fluorescent light emitted from it after the impinging of the ultra-violet rays, the camera lens was protected by a cell containing quinine sulphate solution with some hydrochloric acid, the latter being added to depress the fluorescence of the quinine salt. The details of exposure and the composition of developer are given. The MS is written with silver and gold letters on a purple dyed parchment. The exposure was only two minutes, while with common light an exposure of 300 minutes would be required.

Comparisons of the transmitting powers of the Zeiss UV glass and the Wratten filters were made, and the latter was found to be better adapted to practical work. It is evident that a wide field of investigation yielding both practical and theoretical results is here opened. H. L.

On the Flow of Liquids under Capillary Pressure. E. K. RIDEAL. (*Phil. Mag.*, Dec., 1922.)—"The rate of penetration of liquids into capillary porous materials, of importance not only in biochemical problems, but also in the study of the phenomena of adsorption by materials such as charcoal and substances constituting the membranes of semi-permeable osmometers, has attracted but little attention." To put the problem in concrete form, let a long capillary tube be mounted horizontally with one end open to the air and the other sealed into a vessel containing just enough liquid to cover the mouth of the small tube. Let the liquid be sucked out into the capillary and forced back by compressed air so that the inner walls of the tube be thoroughly wet. At a time when the liquid has been brought well back in the small tube toward the vessel, let external forces be removed. At what velocity will the liquid travel outward through the tube under the action of the forward pull of its meniscus and of the retarding force due to its viscosity? A solution is found in which the velocity is expressed as the sum of a series, which for small values of the radius of the tube reduces to the form already given by Washburn. The square of the velocity equals the time multiplied by a fraction whose numerator is the product of the surface tension by the radius of the tube and whose denominator is

twice the coefficient of viscosity. The square root of this fraction bears the name of "penetration coefficient." The rate of flow was measured by a stop-watch for water and chloroform and for a series of alcohols. When the rate computed from the formula is compared with the observed value excellent agreement is found to exist, especially in the cases of water and chloroform, where the values of the constants needed for calculation are known with accuracy.

G. F. S.

The Variation of the Index of Refraction of Water, Ethyl Alcohol, and Carbon Bisulphide with the Temperature. E. E. HALL and ARTHUR R. PAYNE. (*Phys. Rev.*, Sept., 1922.)—From 1856, when Jamin began the study of the change of the indices of refraction of liquids produced by changes of temperature, the commonest of all liquids has been investigated in this regard, yet but two men have examined the range above 50° C. These, Ruhlman and Kettler, are not always in agreement and, hence, it seemed to repeat the measurements, using all the devices suggested by experience. The temperature of the water was kept constant to .1 degree and an electrically driven stirrer was used to secure uniformity of temperature. "The stirrer and the interior of the brass prism were heavily gold plated. It was found that enough brass would dissolve in the water in the course of a few hours to change the index of refraction by approximately two units in the fourth decimal place." Special care was used to have the liquid free from gases as well as from other impurities.

A spectrometer was employed for the measurements. These for water extended to 98.4°. The index of refraction for water relative to air is at 16°, 1.33333 and at 100°, 1.31783. The rate of change of the index per degree is −.00008 at 15°, but has grown to nearly four times as much at the boiling point. As an illustration of the accuracy with which such measurements have been made it is to be noted that the index at 30° was found by Walter in 1892 to be 1.33194, by Baxter, Burgess and Daudt in 1911 to be 1.33190, while the present authors furnish a result exactly midway between these other two.

G. F. S.

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